GENERAL DYNAMICS | CONVAIR

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Material - Aluminum - 2024-T4 Extrusions

Effect of Stretching on Mechanical and Fatigue Properties

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Effect of Stretching on Mechanical and Fatigue Properties

Abstract:

A large extruded Tee-section made from 2024 aluminum alloy was subjected to fifteen variations in degree of stretch, solution heat treatment and natural aging sequences. The various processing sequences approximated various manufacturing steps, and the mechanical and fatigue properties resulting therefrom were desired for comparison with minimum design allowable strengths already established for unstretched extrusions. In all cases the processed extrusion mechanical and fatigue properties exceeded design minima for unstretched extrusions. In general the strengths were higher than established minima, and the elongations approached minimum values.

Reference: Haney, R. J., Lindeneau, G. D., Wise, W. E., "2024 Extrusions #E-801903 - Effects of Stretching on Tensile Yield, Ultimate & Elongation - Compression Yield - Fatigue Properties - Thickness," General Dynamics/Convair MP 57-997, San Diego, California, 25 June 1958 (Reference attached).

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO

STRUCTURES & MATERIALS LABORATORIES

REPORT 57-997
DATE 25 June 1958
MODEL 22
TEST NO. 57-997
58-049

TITLE

REPORT NO. 57-997

2024 EXTRUSION #E-801903
EFFECTS OF STRETCHING ON;
TENSILE YIELD, ULTIMATE & ELONGATION -
COMPRESSION YIELD - FATIGUE PROPERTIES
- THICKNESS

MODEL 22

PREPARED BY R. J. Haney
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GROUP STRUCTURES LABORATORIES

REFERENCE

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APPROVED BY E. F. Strong
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Chief, Test Laboratories

WITNESS:
R. A. Miller, Structures

NO. OF PAGES 36
NO. OF DIAGRAMS 33

REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED
A	8-12-58	Haney	Added paragraph #3 to Test Specimen description	1

FORM 1812A-4

INTRODUCTION:

Many 2024 extruded sections used in the Model 22 are stretch-formed to obtain the desired contours. Stretch forming causes a reduction in thickness of the part being formed and can produce a substantial change in some mechanical properties, depending on the temper at the time of forming. It is necessary, therefore, to establish a permissible range of stretching, and a temper condition which will produce maximum strength, minimum reduction in thickness, and yet be compatible with production requirements.

OBJECT:

To compare the strengths and reduction in thickness produced by stretching a 2024 extrusion various amounts when in different temper conditions.

TEST SPECIMEN:

The extruded section used for this evaluation is identified by Convair Drawing No. E 801903, and is shown in Figure 1. The extrusion was produced by the Harvey Aluminum Company in the 2024 alloy and delivered to Convair in the "o" condition (2024-0).

The material for this test was cut into sections each six feet long. These lengths were then processed using production facilities and specifications to give test coupon material for the following nominal conditions:

1. No Stretch-Solution Heat Treat
2. Stretch 3% - Solution Heat Treat
3. Stretch 6% - Solution Heat Treat
4. Stretch 10% - Solution Heat Treat
5. Stretch 6% - Solution Heat Treat Stretch 2% in W Condition (after quench)
6. Stretch 6% - Solution Heat Treat Stretch 3% in W Condition (after quench)
7. Stretch 6% - Solution Heat Treat Stretch 4% in W Condition (after quench)
8. Stretch 6% - Solution Heat Treat Stretch 6% in W Condition (3 days)
9. Stretch 6% - Solution Heat Treat Stretch 8% in W Condition (after quench)
10. Stretch 6% - Solution Heat Treat Stretch 10% in W Condition (3 days)
11. Stretch 6% - Solution Heat Treat Stretch 4% after room temperature age.
12. Stretch 6% - Solution Heat Treat - Stretch 6% after room temperature age.
13. Solution Heat Treat - Stretch 0% in W Condition (after quench)
14. Solution Heat Treat - Stretch 3% in W Condition (after quench)
15. Solution Heat Treat - Stretch 6% in W Condition (after quench)
16. Solution Heat Treat - Stretch 10% in W Condition (after quench)

In these cases where the required stretch was 8% or greater, the extrusion web was separated from the flanges for stretching. This was done because the load required for the full cross section exceeded the capacity of the machine.

TEST SPECIMEN:(Continued)

The following types of test coupons were machined from each of the processed extrusions, and are shown in the indicated figures:

1. Standard longitudinal tensile - Figure 2.
2. Sub size longtransverse tensile - Figure 3.
3. Compression Specimen - Figure 4.
4. Unnotched axial fatigue specimen - Figure 5.
5. Unnotched bending fatigue specimen - Figure 6.

The compression, axial fatigue and bending fatigue specimens were also obtained from both the longitudinal and transverse grain directions. In all cases the material was naturally aged for at least four days prior to testing.

Some specimens were taken from the vertical leg of the extrusion. These are identified as "web" specimens, the others as "flange" specimens.

TEST LOADS AND PROCEDURE:

Tension and compression tests were performed in a Tinius-Olsen Electro-Matic Universal testing machine using the automatic strain rate controller to give .005 in./in./minute strain rate to yield, and .2 inch/minute crosshead speed from yield to ultimate. Percent elongation was measured over a 2 inch gage length.

Fatigue tests were performed in a Sonntag SF-1U fatigue machine as shown in Figures 7 and 8. The axial fatigue specimens were tested at four or more stress levels to produce an S-N diagram for each of the test conditions. The stress ratio for the axial fatigue tests was +.05. The bending fatigue specimens were all tested at ± 35,000 PSI, a stress ratio of -1.0.

Thickness measurements were taken at six locations on each leg of the extrusions prior to stretching and after each stretch operation, to provide change in thickness data.

RESULTS AND DISCUSSION OF RESULTS:

The tension and compression test results are given in Tables I and II. Tensile properties are plotted in Figure 14.

RESULTS AND DISCUSSION OF RESULTS:(Continued)

The axial fatigue test results are given in Tables III to X, and are plotted in Figure 9 and 10 as envelope type S-N diagrams. In Figures 11 and 12, the axial fatigue results are plotted against the stretching and temper conditions for each of the test stress levels. In this type of data presentation, trends are indicated by the slope of the average result curve. If the curve slopes to the right, it indicates relative improvement in fatigue life as a result of the processing. A vertical line indicates no change in fatigue life, and a slope to the left represents a loss in life. A trend is significant only if observed at each stress level. Quantative evaluation of results is obtained by comparing the life of the point in question with the life plotted on the abscissa for heat treated but unstretched material.

The reversed bending fatigue results are given in Tables XI to XVIII and are plotted in Figure 13.

The change in material thickness resulting from stretching is given in Table XIX.

CONCLUSIONS:

In all cases the extrusion properties equalled or exceeded the requirements for 2024-T42 material given in ANC-5. In general, the ultimate strengths were considerably higher than 2024-T42 minimums, and elongation values were close to 2024-T42 minimums.

It is important to note that the extrusion used for this evaluation can not be stretched 8% in the full cross section, because the load required exceeds the capacity of the stretching machine.

NOTE: The test Data from which this report was prepared are recorded in Structures Test Laboratory Data Book No. 389, Pages 62 to 89.

Prepared By: F. J. Nance [signature]

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FORM 73

TABLE I
MECHANICAL PROPERTIES STRETCHED 2024 EXTRUSION

Identification of Extrusion By Case Number	Stretch Processing "O" Condition Desired %	"O" Condition Actual %	"W" Condition Desired %	"W" Condition Actual %	Longitudinal Individual Tests Fty Psi	Ftu Psi	Elong. %	Fcy Psi	Longitudinal Averages Fty Psi	Ftu Psi	Elong. %	Fcy Psi	Long Transverse Individual Tests Fty Psi	Ftu Psi	Elong. %	Fcy Psi	Long Transverse Averages Fty Psi	Ftu Psi	Elong. %	Fcy Psi
1	0	0	—	—	52,400	78,850	13.5	53,700					50,200	73,700	18.0	54,600				
..	..	..	—	—	51,615	78,230	13.5	55,100					47,700	73,300	19.0	54,100				
..	.	..	—	—	50,980	77,760	16.0	54,000	51,665	78,280	14.33	54,267	48,000	72,500	19.5	52,600	48,633	73,167	18.8	53,767
2	3	3.2	—	—	42,540	66,400	20.0	44,745					45,600	68,800	9.0	48,360				
..	..	..	—	—	40,950	65,270	21.5	44,965					43,800	66,500	9.0	47,815				
..	..	..	—	—	41,620	65,360	21.5	47,200	41,703	65,677	21.0	45,637	45,800	67,700	8.0	45,800	45,067	67,667	8.7	47,325
3	6	6.25	—	—	42,400	67,125	20.0	47,100					43,400	67,900	11.5	48,600				
..	.	..	—	—	42,140	66,820	20.0	46,800					42,500	67,600	12.0	50,300				
..	.	..	—	—	41,550	66,450	19.5	46,200	42,030	66,798	19.83	46,700	43,640	68,160	14.5	45,000	43,180	67,887	12.7	47,967
4	10	9.45	—	—	40,380	64,930	23.0	46,295					43,750	68,060	11.5	47,150				
..	..	..	—	—	42,250	67,400	21.5	46,675					43,850	68,005	10.5	47,105				
.	..	..	—	—	42,750	67,060	22.5	45,503	41,793	66,463	22.33	45,823	45,000	69,400	12.0	45,600	44,200	68,489	11.3	46,618
5	6	7.64	2	2.21	50,000	66,900	20.5	42,900					45,100	66,400	10.0	51,380				
.	.	..	..	..	50,400	66,330	17.5	45,400					45,900	66,600	9.0	51,060				
..	.	..	..	..	49,540	64,220	19.0	45,100	49,980	65,707	19.0	44,467	46,500	68,300	11.5	44,800	45,833	67,100	10.2	48,980
6	6	5.69	3	3.15	51,300	65,500	16.0	42,300					48,900	68,000	9.0	53,060				
..	.	..	..	..	50,400	64,200	18.5	44,400					47,900	67,400	8.0	54,145				
..	.	..	..	..	51,330	64,260	21.0	43,220	51,010	64,653	18.5	43,307	46,900	66,800	9.0	49,700	47,900	67,400	8.7	52,302
7	6	5.97	4	4.72	54,000	66,300	20.0	44,900					49,000	67,600	11.0	52,835				
..	.	..	..	..	54,400	66,300	16.0	45,800					48,600	67,200	10.0	54,880				
..	.	..	..	..	51,400	64,485	19.0	39,750	53,267	65,695	18.33	43,483	48,700	67,400	10.0	54,400	48,767	67,400	10.3	54,038
9	6	6.53	6	6.00	56,100	66,500	13.5	45,300					48,270	67,195	10.0	55,020				
.	..	..	..	..	55,700	66,800	15.5	44,900					48,800	68,000	11.5	54,955				
..		..	.	..	54,600	64,175	15.5	47,145	55,467	65,525	14.83	45,782	48,370	67,335	11.0	55,100	48,480	67,510	10.8	55,025
11	6	6.39	8	6.93 } Flange	55,600	64,600	19.0	47,000					52,965	68,375	6.0	56,565				
.		..	.	6.93 } Flange	56,800	66,000	15.5	47,200					54,600	70,200	6.0	56,526				
.		..	.	7.36-Web	57,585	66,360	15.0	45,715	56,662	65,553	16.5	46,638	53,120	69,055	7.0	56,500	53,562	69,210	6.3	56,530
12	6	5.83	10	10.25 } Flange	61,000	67,200	11.0	52,300					53,000	66,500	4.0	62,060				
..		..	.	10.25 } Flange	61,500	67,900	9.0	51,700					54,000	68,100	4.0	59,405				
..		..		11.00-Web	61,600	67,760	15.0	49,795	61,367	67,620	11.67	51,265	54,000	67,200	3.5	58,900	53,667	67,267	3.8	60,122
8	6	5.83	* 4	4.02 } Flange	58,300	67,400	15.0	50,200					55,000	72,200	7.0	60,225				
.		..	..	4.02 } Flange	60,000	69,700	11.0	50,800					53,300	71,700	9.0	62,100				
		..	..	3.89-Web	57,140	68,095	19.5	49,175	58,480	68,398	15.17	50,058	53,900	72,100	8.5	58,100	54,067	72,000	8.2	60,142
10	6	6.39	* 6	6.4 } Flange	64,200	71,200	17.0	54,000					57,100	72,000	9.5	62,500				
.		..	.	6.4 } Flange	64,900	71,000	13.0	53,200					57,840	72,540	11.0	63,230				
		..	..	5.7-Web	63,315	69,645	16.0	50,380	63,840	70,615	15.33	52,527	56,000	72,200	10.0	60,600	56,980	72,247	10.2	62,110

* Stretching performed three (3) days after quench.

Prepared by: F. J. Lanto
H. Hickelman

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FORM 73

TABLE II
MECHANICAL PROPERTIES STRETCHED 2024 EXTRUSION

Identification Extrusion & Specimen	Stretch after Quench %	Flange or Web Location	Longitudinal Mechanical Properties – Individual Tests Fty, psi	Ftu, psi	% Elong.	Fcy, psi	Longitudinal – Averages Fty, psi	Ftu, psi	% Elong.	Fcy, psi	Long Transverse Mechanical Properties – Individual Tests Fty, psi	Ftu, psi	% Elong.	Fcy, psi	Long Transverse – Averages Fty, psi	Ftu, psi	% Elong.	Fcy, psi
13-1	0	Flange	45,695	70,645	17.0	54,100					48,076	75,961	11.5	54,600				
-2	"	"	49,425	77,873	17.0	54,300	47,560	74,259	17.0	54,200	50,766	69,923	7.0	53,500				54,050
-3	"	"									51,060	75,144	9.0		49,967	73,676	9.17	
13-1	"	Web	44,941	71,011	17.5	53,800								53,700				
-2	"	"	51,737	79,440	15.5	53,400	48,339	75,225	16.5	53,600				53,800				53,750
-3	"	"																
14-1	3.0	Flange	64,258	78,034	14.0	43,500					51,063	70,406	8.0	54,000				
-2	"	"	54,440	68,146	13.0	43,300	59,349	73,090	13.5	43,400	51,923	72,115	9.0	54,900				54,450
-3	"	"									52,224	72,340	9.0		51,737	71,620	8.67	
14-1	"	Web	51,136	64,772	15.0	48,200								60,500				
-2	"	"	60,526	72,744	10.0	53,700	55,831	68,758	12.5	5[illegible],950				60,500				60,500
-3	"	"																
15-1	6.0	Flange	65,317	77,167	10.0	60,400					56,862	73,921	6.0	64,900				
-2	"	"	57,309	66,081	13.0	58,300	61,313	71,624	11.5	59,350	56,429	73,704	5.5	64,100				64,500
-3	"	"									58,479	75,048	5.5		57,257	74,224	5.67	
15-1	6.13	Web	55,576	65,973	12.0	52,600								65,300				
-2	"	"	65,654	75,332	9.5	57,900	60,615	70,652	10.75	55,250				64,800				65,050
-3	"	"																
16-1	8.95	Flange	69,439	77,562	10.0	53,509					56,190	72,380	5.0	69,951				
-2	"	"	56,666	65,490	17.5	62,318	63,052	71,526	13.75	57,913	57,034	71,577	5.5	68,884				69,417
-3	"	"									57,471	70,881	5.0		56,898	71,613	5.17	
16-1	"	Web	65,551	77,362	9.0	47,214								60,544				
-2	"	"	62,840	76,459	12.0	56,105	64,195	76,910	10.5	51,159				61,116				60,830
-3	"	"																

Prepared by: R. J. Haney
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TABLE III

AXIAL FATIGUE TEST RESULTS – STRETCHED 2024 EXTRUSIONS

SPEC. GROUP	PROCESSING APPLIED TO EXTRUSION	① LOCATION	② GRAIN	ROCKWELL E	MAX SURFIN (μ IN) L	MAX SURFIN (μ IN) T	MAX STRESS ③ (PSI)	CYCLES TO FAILURE ④
1	NO STRETCH -- SOLUTION HEAT TREAT	F	T	101.4	16	27	55,000	42,000
"	" " " " " "	F	T	102.9	14	28	50,000	67,000
"	" " " " " "	F	T	100.6	16	29	45,000	217,000
"	" " " " " "	W	T	98.8	10	21	42,500	300,000
"	" " " " " "	F	T	99.5	12	20	40,000	1,613,000 U
"	" " " " " "	F	L	102.0	27	26	55,000	27,000
"	" " " " " "	F	L	97.5	17	29	50,000	111,000
"	" " " " " "	W	L	101.0	9	23	45,000	302,000
"	" " " " " "	F	L	99.6	17	24	42,500	80,000
"	" " " " " "	F	L	101.2	14	28	40,000	454,000
"	" " " " " "	W	L	100.3	9	25	37,500	6,825,000 U
2	STRETCHED 3.2% THEN SOL. HEAT TREATED	F	T	102.5	18	22	55,000	15,000
"	" " " " " "	F	T	101.6	20	27	50,000	23,000
"	" " " " " "	F	T	101.9	24	22	45,000	126,000
"	" " " " " "	W	T	98.3	12	22	42,500	153,000
"	" " " " " "	F	T	100.9	9	16	40,000	6,585,000 U
"	" " " " " "	F	L	99.5	10	24	55,000	28,000
"	" " " " " "	F	L	100.0	15	24	50,000	38,000
"	" " " " " "	F	L	100.8	13	27	45,000	59,000
"	" " " " " "	F	L	100.4	16	27	40,000	212,000
"	" " " " " "	W	L	100.5	12	18	37,500	544,000
"	" " " " " "	W	L	101.3	9	20	35,000	1,997,000 U

① W=WEB F=FLANGE 2. L=LONGITUDINAL, T=TRANSVERSE ③ R=+.05 ④ U=UNFAILED

Prepared By: R. J. Haney
G. Lindenau

TABLE IV

AXIAL FATIGUE TEST RESULTS — STRETCHED 2024 EXTRUSIONS

SPEC. GROUP	PROCESSING APPLIED TO EXTRUSION	LOCATION ①	GRAIN ②	ROCKWELL "E"	MAX. SURF. FIN (μ in) L	MAX. SURF. FIN (μ in) T	MAX. STRESS (PSI) ③	CYCLES TO FAILURE ④
3	STRETCHED 6.3 % THEN SOL. H.T.	F	T	101.7	11	20	55,000	26,000
"	"	F	T	101.0	11	22	50,000	85,000
"	"	F	T	100.5	8	22	45,000	43,000
"	"	W	T	101.0	11	20	45,000	59,000
"	"	W	T	101.7	10	20	42,500	79,000
"	"	F	T	101.4	11	23	40,000	1,437,000 U
"	"	F	L	101.8	11	18	55,000	19,000
"	"	F	L	100.6	14	22	50,000	51,000
"	"	F	L	101.2	10	14	45,000	64,000
"	"	W	L	100.1	10	26	42,500	92,000
"	"	F	L	98.6	12	21	40,000	966,000
4	STRETCHED 9.5 % THEN SOL. H.T.	F	T	102.6	12	50	55,000	23,000
"	"	F	T	102.5	8	18	50,000	47,000
"	"	F	T	102.5	13	53	45,000	75,000
"	"	W	T	101.8	11	21	42,500	235,000
"	"	F	T	101.0	13	21	40,000	1,035,000 U
"	"	F	L	100.4	17	20	55,000	21,000
"	"	F	L	99.9	10	20	50,000	39,000
"	"	F	L	102.4	14	21	45,000	73,000
"	"	W	L	101.3	15	23	42,500	67,000
"	"	W	L	101.2	13	18	40,000	1,000
"	"	F	L	100.1	21	23	40,000	1,471,000 U

① W = WEB, F = FLANGE ② L = LONGITUDINAL, T = TRANSVERSE ③ R = +.05 ④ U = UNFAILED

Prepared By R. J. Hanley
H. Lindencamp

TABLE V

AXIAL FATIGUE TEST RESULTS — STRETCHED 2024 EXTRUSIONS

SPEC GROUP	PROCESSING APPLIED TO EXTRUSION	LOCATION ①	GRAIN ②	ROCKWELL "E"	MAX. SURF FIN (μ IN) L	MAX. SURF FIN (μ IN) T	MAX. STRESS (PSI) ③	CYCLES TO FAILURE ④
5	STR. 6% SOL. H.T. STRETCH 2.2% IN W" COND.	F	T	101.5	11	24	55,000	12,000
"	" " " " " "	F	T	99.9	35	100	50,000	41,000
"	" " " " " "	F	T	101.0	11	20	45,000	115,000
"	" " " " " "	F	T	100.1	35	90	40,000	147,000
"	" " " " " "	W	T	100.5	10	22	37,500	1,844,000 U
"	" " " " " "	F	L	100.0	13	22	55,000	21,000
"	" " " " " "	F	L	100.5	19	57	50,000	31,000
"	" " " " " "	F	L	100.0	12	22	45,000	126,000
"	" " " " " "	F	L	104.5	16	30	40,000	315,000
"	" " " " " "	W	L	100.7	16	30	37,500	605,000
"	" " " " " "	W	L	101.0	14	28	35,000	407,000
6	STR. 6% SOL. H.T. STRETCH 3.2% IN W" COND.	F	T	101.8	10	20	55,000	21,000
"	" " " " " "	F	T	98.8	11	26	50,000	35,000
"	" " " " " "	F	T	101.9	11	35	45,000	86,000
"	" " " " " "	F	T	101.5	11	36	40,000	370,000
"	" " " " " "	W	T	100.1	13	38	37,500	1,594,000 U
"	" " " " " "	F	L	102.0	15	45	55,000	17,000
"	" " " " " "	F	L	103.3	13	44	50,000	38,000
"	" " " " " "	F	L	102.0	17	75	45,000	219,000
"	" " " " " "	F	L	103.0	16	29	40,000	252,000
"	" " " " " "	W	L	101.3	15	70	37,500	2,382,000 U

① W=WEB, F=FLANGE ② L=LONGITUDINAL, T=TRANSVERSE ③ K=1.05 ④ U=UNFAILED

Prepared By R. J. Hauer
A. Lindeman

TABLE VI

AXIAL FATIGUE TEST RESULTS – STRETCHED 2024 EXTRUSIONS

SPEC. GROUP	PROCESSING APPLIED TO EXTRUSION	LOCATION ①	GRAIN ②	ROCKWELL "E"	MAX. SURF. FIN (μ IN.) L	MAX. SURF. FIN (μ IN.) T	MAX STRESS (PSI) ③	CYCLES TO FAILURE ④
7	STRETCH 6% SOL. H.T. STRETCH 4.7% IN W COND	F	T	102.1	14	25	55,000	19,000
"	" " " " " "	F	T	100.5	25.5	72.5	50,000	56,000
"	" " " " " "	F	T	101.9	12	24	45,000	108,000
"	" " " " " "	F	T	101.5	12	68	40,000	298,000
"	" " " " " "	W	T	103.0	15	24	35,000	1,293,000 U
"	" " " " " "	F	L	103.3	12	22	55,000	20,000
"	" " " " " "	F	L	102.5	13	28	50,000	61,000
"	" " " " " "	F	L	102.7	12	24	45,000	117,000
"	" " " " " "	W	L	102.8	15	25	42,500	800,000
"	" " " " " "	F	L	103.4	16	35	40,000	1,484,000
11	STRETCH 6% SOL. H.T. STRETCH 4% AFTER R.T. AGE	F	T	102.7	14	24	55,000	23,000
"	" " " " " "	F	T	104.3	16	24	50,000	65,000
"	" " " " " "	F	T	103.0	13	24	45,000	129,000
"	" " " " " "	F	T	104.0	20	22	42,500	459,000
"	" " " " " "	F	T	104.5	15	21	40,000	1,517,000
"	" " " " " "	F	L	105.9	20	28	55,000	14,000
"	" " " " " "	F	L	102.7	14	23	50,000	65,000
"	" " " " " "	F	L	105.5	10	24	45,000	139,000
"	" " " 3.9% "	W	L	104.1	13	24	42,500	737,000
"	" " " 4% "	F	L	103.8	13	23	40,000	1,162,000 U

① W = WEB, F = FLANGE ② L = LONGITUDINAL, T = TRANSVERSE ③ R = +.05 ④ U = UNFAILED

TABLE VII

AXIAL FATIGUE TEST RESULTS – STRETCHED 2024 EXTRUSIONS

SPEC. GROUP	PROCESSING APPLIED TO EXTRUSION	LOCATION ①	GRAIN ②	ROCKWELL "E"	MAX. SURFACE STRAIN (in/in) L	MAX. SURFACE STRAIN (in/in) T	MAX. STRESS (PSI) ③	CYCLES TO FAILURE ④
8	STRETCH 6% SOL. H.T. STRETCH 6% IN "W" COND.	F	T	102.2	13	21	55,000	1,000
"	" " " " " "	W	T	101.8	8	22	55,000	40,000
"	" " " " " "	F	T	101.5	13	50	50,000	44,000
"	" " " " " "	F	T	102.1	16	26	45,000	75,000
"	" " " " " "	W	T	101.8	11	23	42,500	1,557,000
"	" " " " " "	F	T	101.3	13	28	40,000	1,000,000 U
"	" " " " " "	F	L	102.1	13	25	55,000	1,000
"	" " " " " "	W	L	102.1	11	23	55,000	58,000
"	" " " " " "	F	L	103.0	13	24	50,000	55,000
"	" " " " " "	F	L	101.4	16	27	45,000	106,000
"	" " " " " "	W	L	101.4	14	25	42,500	346,000
"	" " " " " "	F	L	102.5	14	22	40,000	1,079,000 U
12	STRETCH 6% SOL H.T. STRETCH 6.4% AFTER R.T. AGE	F	T	105.5	12	30	55,000	55,000
"	" " " " " "	F	T	104.7	13	43	50,000	68,000
"	" " " " " "	F	T	104.2	13	58	45,000	157,000
"	" " " " " "	F	T	104.5	15	55	45,000	169,000
"	" " " " " "	F	T	104.3	20	28	42,500	1,164,000 U
"	" " " " " "	F	T	102.9	12	21	40,000	1,019,000 U
"	" " " " " "	F	L	104.4	17	60	55,000	81,000
"	" " " " " "	F	L	105.3	12	24	50,000	127,000
"	" " " " " "	F	L	104.5	13	60	45,000	124,000
"	" " " " 5.7% "	W	L	103.5	15	65	42,500	348,000
"	" " " " 6.4% "	F	L	104.2	13	25	40,000	844,000
"	" " " " 5.7% "	W	L	103.6	13	60	37,500	1,962,000 U

① W = WEB, F = FLANGE, ② L = LONGITUDINAL, T = TRANSVERSE ③ K = 1.05 ④ U = UNFAILED

Prepared By: F. D. Hanly
A. Henderson

TABLE VIII

AXIAL FATIGUE TEST RESULTS — STRETCHED 2024 EXTRUSIONS

SPEC. GROUP.	PROCESSING APPLIED TO EXTRUSION	LOCATION ①	GRAIN ②	ROCKWELL "E"	MAX SURF. FIN. (μ IN.) L	MAX SURF. FIN. (μ IN.) T	MAX STRESS (PSI) ③	CYCLES TO FAILURE ④
9	STRETCH 6% SOL. H.T. STRETCH 6.9% IN W" COND	F	T	103.8	10	26	55,000	21,000
"	" " " " " " "	F	T	101.9	13	60	50,000	43,000
"	" " " " " " "	F	T	102.2	17	29	45,000	99,000
"	" " " " " " "	F	T	100.9	8	43	40,000	220,000
"	" " " " " " "	F	T	102.3	16	30	37,500	1,976,000
"	" " " " " " "	F	L	102.3	14	26	55,000	12,000
"	" " " " " " "	F	L	103.5	20	27	50,000	90,000
"	" " " " " " "	F	L	102.4	16	27	45,000	229,000
"	" " " " 7.4% "	W	L	103.2	14	25	42,500	100,000
"	" " " " 7.4% "	W	L	103.6	14	27	42,500	784,000
"	" " " " 6.9% "	F	L	104.3	14	27	40,000	1,128,000 U
10	STRETCH 6% SOL. H.T. STRETCH 10.3% IN W" COND	F	T	103.7	13	23	55,000	17,000
"	" " " " " " "	F	T	103.7	11	17	50,000	84,000
"	" " " " " " "	F	T	104.5	13	20	45,000	237,000
"	" " " " " " "	F	T	102.9	10	17	40,000	626,000
"	" " " " " " "	F	T	103.8	15	27	37,500	1,104,000 U
"	" " " " " " "	F	L	104.5	10	26	55,000	22,000
"	" " " " " " "	F	L	104.7	14	23	50,000	69,000
"	" " " " " " "	F	L	103.9	9	22	45,000	162,000
"	" " " " " " "	F	L	104.9	12	19	40,000	622,000
"	" " " " 10.0% "	W	L	104.2	10	27	37,500	1,176,000 U

① W = WEB, F = FLANGE ② L = LONGITUDINAL, T = TRANSVERSE ③ R = 1.05 ④ U = UNFAILED

Prepared By: R. J. Haney
H. Lindemann

TABLE IX

AXIAL FATIGUE TEST RESULTS — STRETCHED 2024 EXTRUSIONS

GROUP	PROCESSING APPLIED TO EXTRUSIONS	LOCATION ①	GRAIN ②	ROCKWELL "B"	MAX SURFACE FAILURE (IN.) L	MAX SURFACE FAILURE (IN.) T	MAX STRESS (PSI) ③	CYCLES TO FAILURE ④
13	SOLUTION H.T. NO STRETCH	F	T	99.3	14	24	55,000	48,000
"	" " "	F	T	101.5	14	26	50,000	90,000
"	" " "	F	T	100.8	13	23	45,000	159,000
"	" " "	F	T	100.5	12	24	42,500	1,083,000 U
"	" " "	F	T	101.5	15	22	40,000	1,083,000 U
"	" " "	F	L	100.0	14	27	55,000	19,000
"	" " "	F	L	100.0	16	27	50,000	34,000
"	" " "	F	L	101.0	13	27	SPECIMEN WARPED	
"	" " "	F	L	100.9	16	29	45,000	56,000
"	" " "	F	L	100.0	17	29	42,500	133,000
"	" " "	F	L	100.4	16	26	40,000	1,149,000 U
14	SOLUTION H.T. THEN 3% STRETCH	F	T	102.0	14	27	55,000	24,000
"	" " " "	F	T	102.5	13	27	50,000	82,000
"	" " " "	F	T	102.4	13	24	45,000	260,000
"	" " " "	F	T	102.5	10	31	42,500	187,000
"	" " " "	F	T	104.0	14	26	40,000	1,018,000
"	" " " "	F	L	101.0	14	26	55,000	24,000
"	" " " "	F	L	101.9	14	28	50,000	88,000
"	" " " "	F	L	101.6	13	26	45,000	133,000
"	" " " "	F	L	101.1	12	25	41,400	240,000
"	" " " "	F	L	101.5	14	28	40,000	470,000
"	" " " "	F	L	102.1	12	26	40,000	534,000

① W=WEB, F=FLANGE, ② L=LONGITUDINAL, T=TRANSVERSE ③ R=+.05 ④ U=UNFAILED

Prepared By R. J. Hauer
A. Lindemann

TABLE X

AXIAL FATIGUE TEST RESULTS — STRETCHED 2024 EXTRUSIONS

SPEC. GROUP	PROCESSING APPLIED TO EXTRUSION	① LOCATION	② GRAIN	ROCKWELL L "E"	MAX SURF FIN. (μ IN) L	MAX SURF FIN. (μ IN) T	MAX. STRESS (PSI) ③	CYCLES TO FAILURE ④
15	SOLUTION H.T. THEN 6% STRETCH	F	T	103.5	12	21	55,000	61,000
"	" " " "	F	T	104.7	14	28	50,000	181,000
"	" " " "	F	T	103.8	12	23	45,000	334,000
"	" " " "	F	T	104.0	10	19	42,500	459,000
"	" " " "	F	T	104.3	10	19	40,000	6,460,000
"	" " " "	F	L	103.0	12	28	55,000	52,000
"	" " " "	F	L	103.8	13	27	50,000	135,000
"	" " " "	F	L	104.2	13	25	45,000	67,000
"	" " " "	F	L	103.2	15	23	40,000	121,000
"	" " " "	F	L	104.0	18	25	40,000	321,000
"	" " " "	F	L	104.0	15	24	37,500	198,000
16	SOLUTION H.T. THEN 10% STRETCH	F	T	104.0	16	25	55,000	21,000
"	" " " "	F	T	104.5	15	24	50,000	93,000
"	" " " "	F	T	104.2	14	21	45,000	169,000
"	" " " "	F	T	104.0	15	21	40,000	292,000
"	" " " "	F	T	104.0	19	21	37,500	1,450,000 U
"	" " " "	F	L	104.3	15	26	55,000	35,000
"	" " " "	F	L	103.3	17	22	50,000	97,000
"	" " " "	F	L	103.0	18	24	45,000	147,000
"	" " " "	F	L	104.0	15	21	40,000	312,000
"	" " " "	F	L				SPECIMEN	WARPED
"	" " " "	F	L	103.5	15	26	37,500	1,123,000

① W = WEB, F = FLANGE ② L = LONGITUDINAL, T = TRANSVERSE ③ R = ±.05 ④ U = UNFAILED

TABLE II

Prepared By: R. J. Kane
H. Lindeman

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX. STRESS ± 35,000 P.S.I. (R = -1)

SPEC. GROUP	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX. SURFACE FINISH μ-IN. LONG.	MAX. SURFACE FINISH μ-IN. TRANS.	CYCLES TO FAILURE	REMARKS
1	NO STRETCH – SOLUTION HEAT TREAT	TRANS.	99.9	12	21	136,000	
"	" " " " "	"	99.1	13	24	118,000	
"	" " " " "	"	99.7	11	22	115,000	
"	NO STRETCH – SOLUTION HEAT TREAT	TRANS.	99.1	10	19	129,000	
	AVERAGE		99.45	11.5	21.5	124,500	
"	NO STRETCH – SOLUTION HEAT TREAT	LONG.	102.2	10	18	134,000	
"	" " " " "	"	102.2	14	22	76,000	
"	" " " " "	"	101.4	15	25	140,000	
"	NO STRETCH – SOLUTION HEAT TREAT	LONG.	99.9	14	26	39,000	
	AVERAGE		101.4	13.25	22.75	97,250	
2	STRETCH 3.2% – SOLUTION HEAT TREAT	TRANS.	100.0	11	23	88,000	
"	" " " " "	"	100.0	13	20	74,000	
"	" " " " "	"	100.5	14	22	69,000	
"	STRETCH 3.2% – SOLUTION HEAT TREAT	TRANS.	99.8	14	28	89,000	GRIP FAILURE
	AVERAGE		100.1	13	23.25	80,000	
"	STRETCH 3.2% – SOLUTION HEAT TREAT	LONG.	100.4	11	20	79,000	
"	" " " " "	"	101.9	12	20	78,000	
"	" " " " "	"	99.8	11	26	231,000	GRIP FAILURE
"	STRETCH 3.2% – SOLUTION HEAT TREAT	LONG.	99.4	11	23	244,000	
	AVERAGE		100.4	11.25	22.25	158,000	

L = LONGITUDINAL
T = TRANSVERSE
ALL FAILURES OCCURRED IN TEST SECTION EXCEPT AS NOTED.

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TABLE XII

Prepared By: R. J. Haney
C. H. Lindabury

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX. STRESS ±35,000 P.S.I. (R=-1)

SPEC. GROUP	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX. SURFACE FINISH μ-IN. LONG.	MAX. SURFACE FINISH μ-IN. TRANS.	CYCLES TO FAILURE	REMARKS
3	STRETCH 6.3% - SOLUTION HEAT TREAT	TRANS.	101.4	14	24	43,000	
"	" " " " "	"	99.8	11	18	110,000	
"	" " " " "	"	100.0	16	25	65,000	
"	STRETCH 6.3% - SOLUTION HEAT TREAT	TRANS.	99.3	14	23	61,000	
	AVER.		100.1	13.75	22.50	69,750	
"	STRETCH 6.3% - SOLUTION HEAT TREAT	LONG.	101.4	12	17	149,000	
"	" " " " "	"	102.1	12	24	139,000	GRIP FAILURE
"	" " " " "	"	101.0	13	21	103,000	
"	STRETCH 6.3% - SOLUTION HEAT TREAT	LONG.	100.1	14	26	158,000	
	AVER.		101.15	12.75	22	137,250	
4	STRETCH 9.5% - SOLUTION HEAT TREAT	TRANS.	100.7	13	25	63,000	
"	" " " " "	"	100.5	12	18	78,000	
"	" " " " "	"	100.5	18	29	78,000	
"	STRETCH 9.5% - SOLUTION HEAT TREAT	TRANS.	101.3	13	21	86,000	
	AVER.		100.75	14	23.25	76,250	
"	STRETCH 9.5% - SOLUTION HEAT TREAT	LONG.	102.0	11	21	297,000	
"		"	101.5	9	17	255,000	GRIP FAILURE
"		"	99.7	12	29	87,000	
"	STRETCH 9.5% - SOLUTION HEAT TREAT	LONG.	100.8	13	22	82,000	
	AVER.		101.0	11.25	22.25	182,500	

L = LONGITUDINAL
T = TRANSVERSE
ALL FAILURES OCCURRED IN TEST SECTION EXCEPT AS NOTED.

Prepared By. R. J. Kenny
H. Lindemann

TABLE XIII

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX. STRESS ±35,000 PSI (R = -1)

SPEC. GROUP	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX. SURFACE FINISH μ-IN.		CYCLES TO FAILURE	REMARKS
5	STRETCH 6% - SOL. H.T. - STRETCH 2% IN W COND.	TRANS.	100.3	12	55	100,000	
"	" " " " " " " "	"	101.5	12	19	74,000	
"	" " " " " " " "	"	101.0	11	19	53,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 2% IN W COND.	TRANS.	100.0	14	26	69,000	
	AVER.		100.7	12.25	29.75	74,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 2% IN W COND.	LONG.	102.3	9	18	71,000	
"	" " " " " " " "	"	100.8	14	21	47,000	
"	" " " " " " " "	"	101.0	13	35	48,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 2% IN W COND.	LONG	100.5	11	21	43,000	
	AVER.		101.15	11.75	23.75	52,250	
6	STRETCH 6% - SOL. H.T. - STRETCH 3% IN W COND.	TRANS.	102.2	12	20	50,000	
"	" " " " " " " "	"	102.2	15	23	88,000	
"	" " " " " " " "	"	102.3	13	26	65,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 3% IN W COND.	TRANS.	103.0	11	23	76,000	
	AVER.		102.4	12.75	23	69,750	
"	STRETCH 6% - SOL. H.T. - STRETCH 3% IN W COND.	LONG.	101.5	15	25	330,000	
"	" " " " " " " "	"	105.0	13	26	104,000	
"	" " " " " " " "	"	102.7	14	25	55,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 3% IN W COND.	LONG.	102.3	15	25	80,000	
	AVER.		102.9	14.25	25.25	79,670	

TRANS. = TRANSVERSE
LONG. = LONGITUDINAL
ALL FAILURES OCCURED IN TEST SECTION EXCEPT AS NOTED.

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Prepared By R. J. Hanley
& Lindenau

TABLE XIV

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX. STRESS ±35,000 P.S.I. (R=-1)

SPEC. GROUP	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX. SURFACE FINISH μ-IN LONG.	MAX. SURFACE FINISH μ-IN TRANS	CYCLES TO FAILURE	REMARKS
7	STRETCH 6% – SOL. H.T. – STRETCH 4.7% IN W COND	TRANS.	100.7	12	21	65,000	
"	" " " " " " " "	"	101.3	15	20	80,000	
"	" " " " " " " "	"	101.1	11	28	64,000	
"	STRETCH 6% – SOL. H.T. – STRETCH 4.7% IN W COND	TRANS.	101.6	13	25	51,000	
	AVER.		101.2	12.75	23.50	65,000	
"	STRETCH 6% – SOL. H.T. – STRETCH 4.7% IN W COND	LONG.	102.8	16	21	89,000	
"	" " " " " " " "	"	103.1	13	19	52,000	
"	" " " " " " " "	"	101.1	14	28	86,000	
"	STRETCH 6% – SOL. H.T. – STRETCH 4.7% IN W COND.	LONG	101.2	13	21	85,000	
	AVER.		102.05	14	22.25	78,000	
//	STRETCH 6% – SOL. H.T. – STRETCH 4% AFTER ROOM TEMP. AGE	TRANS.	102.0	11	17	20,000	GRIP FAILURE
"	" " " " " " " "	"	106.0	12	18	—	OVERLOADED
"	" " " " " " " "	"	103.1	15	28	84,000	GRIP FAILURE
"	STRETCH 6% – SOL. H.T. – STRETCH 4% AFTER ROOM TEMP. AGE	TRANS.	102.7	18	27	55,000	
	AVER.		102.95	14	22.5	53,000	
"	STRETCH 6% – SOL. H.T. – STRETCH 4% AFTER ROOM TEMP. AGE	LONG	103.5	12	19	99,000	
"	" " " " " " " "	"	104.0	13	20	121,000	
"	" " " " " " " "	"	102.2	14	23	54,000	
"	STRETCH 6% – SOL. H.T. – STRETCH 4% AFTER ROOM TEMP. AGE	LONG	102.1	15	27	82,000	
	AVER.		102.95	13.5	22.25	89,000	

TRANS = TRANSVERSE
LONG = LONGITUDINAL

ALL FAILURES OCCURRED IN TEST SECTION EXCEPT AS NOTED.

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TABLE XV

Prepared By R. J. Haney / D. Lindineau

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX. STRESS ± 35,000 P.S.I. (R = -1)

SPEC.	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX. SURFACE FINISH µ-IN.		CYCLES TO FAILURE	REMARKS
8	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	TRANS.	102.4	13	21	75,000	
"	" " " " " " " "	"	102.5	12	20	72,000	
"	" " " " " " " "	"	101.6	12	23	74,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	TRANS	102.5	18	25	78,000	
	AVER.		102.25	13.75	22.25	74,750	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	LONG.	102.1	13	23	100,000	
"	" " " " " " "	"	102.0	12	19	66,000	
"	" " " " " " "	"	102.2	12	21	36,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	LONG.	101.9	14	22	59,000	
	AVER.		102.05	12.75	21.25	65,250	
12	STRETCH 6% - SOL. H.T. - STRETCH 6% AFTER R.T. AGE	TRANS.	104.4	17	24	82,000	
"	" " " " " " " "	"	104.0	9	23	63,000	
"	" " " " " " " "	"	104.5	14	27	93,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% AFTER R.T. AGE	TRANS.	103.8	14	22	103,000	
	AVER.		104.18	13.5	24	85,250	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% AFTER R.T. AGE	LONG.	106.5	11	19	85,000	
"		"	104.3	14	22	67,000	
"		"	105.0	11	20	117,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% AFTER R.T. AGE	LONG.	104.4	12	21	119,000	
	AVER.		105.05	12	20.5	97,000	

LONG. = LONGITUDINAL
TRANS. = TRANSVERSE

ALL FAILURES OCCURRED IN TEST SECTION EXCEPT AS NOTED.

TABLE XVI

Prepared By: R. J. Honey
A. Lindeneau

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX. STRESS ±35,000 P.S.I. (R = -1)

SPEC. GROUP	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX. SURFACE FINISH μ-IN		CYCLES TO FAILURE	REMARKS
9	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	TRANS.	102.5	15	24	56,000	
"	" " " " " " " "	"	103.0	10	21	74,000	
"	" " " " " " " "	"	102.5	14	23	87,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	TRANS.	102.2	17	26	63,000	
	AVER.		102.55	14	23.5	70,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	LONG.	103.0	15	23	96,000	
"	" " " " " " " "	"	101.5	12	21	119,000	GRIP FAILURE
"	" " " " " " " "	"	102.3	10	21	105,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 6% IN W COND.	LONG	102.0	10	19	144,000	
	AVER.		102.2	11.75	21	116,000	
10	STRETCH 6% - SOL. H.T. - STRETCH 10.3% IN W COND.	TRANS.	103.6	10	19	39,000	
"	" " " " " " " "	"	104.3	16	23	27,000	
"	" " " " " " " "	"	104.6	12	19	70,000	GRIP FAILURE
"	STRETCH 6% - SOL. H.T. - STRETCH 10.3% IN W COND.	TRANS.	103.5	14	25	103,000	
	AVER.		104.0	13	22	59,750	
"	STRETCH 6% - SOL. H.T. - STRETCH 10.3% IN W. COND.	LONG.	106.0	9	19	84,000	
"	" " " " " " " "	"	104.9	10	21	56,000	
"	" " " " " " " "	"	104.5	12	23	60,000	
"	STRETCH 6% - SOL. H.T. - STRETCH 10.3% IN W. COND.	LONG	103.8	14	24	36,000	
	AVER.		104.8	11.25	21.75	59,500	

TRANS. = TRANSVERSE
LONG = LONGITUDINAL

ALL FAILURES OCCURRED IN TEST SECTION EXCEPT AS NOTED.

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Model 22
Date 26 June 1958

TABLE XVII

Prepared By R. J. Hoyt
A. Lindeheim

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX. STRESS ±35,000 P.S.I. (R=-1)

SPEC. GROUP	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX SURFACE FINISH μ-IN.		CYCLES TO FAILURE	REMARKS
13	NO STRETCH-SOL H.T. IN "W" CONDITION	TRANS	101.5	12	17	128,000	
"	" " " " " "	"	102.0	11	15	195,000	
"	" " " " " "	"	102.0	10	15	230,000	
"	NO STRETCH-SOL H.T. IN "W" CONDITION	TRANS	101.0	13	24	217,000	
	AVERAGE		101.6	11.5	17.8	192,500	
"	NO STRETCH-SOL.H.T. IN "W" CONDITION	LONG.	100.8	16	24	122,000	
"	" " " " " "	"	99.9	17	27	171,000	
"	" " " " " "	"	100.2	17	27	395,000	
"	NO STRETCH-SOL. H.T. IN "W" CONDITION	LONG.	100.0	16	25	144,000	
	AVERAGE		100.2	16.5	25.5	216,000	
14	NO STRETCH-SOL.H.T. STRETCHED 3% IN "W" COND.	TRANS.	102.9	12	16	127,000	GRIP FAILURE
"	" " " " " " "	"	101.9	14	19	129,000	" "
"	" " " " " " "	"	102.3	13	16	177,000	
"	NO STRETCH-SOL. H.T. STRETCHED 3% IN "W" COND	TRANS	102.0	14	26	188,000	
	AVERAGE		102.3	13.25	16.75	155,250	
"	NO STRETCH-SOL.H.T. STRETCHED 3% IN "W" COND.	LONG.	102.0	17	26	104,000	
"	" " " " " " "	"	101.5	16	25	159,000	
"	" " " " " " "	"	101.0	14	24	151,000	
"	NO STRETCH-SOL.H.T. STRETCHED 3% IN "W" COND	LONG.	101.0	13	23	99,000	
			101.4	15	24.5	128,250	

LONG. = LONGITUDINAL
TRANS. = TRANSVERSE
ALL FAILURES OCCURRED IN TEST SECTION EXCEPT AS NOTED.

Prepared By R. J. Haney
H. Linderleaw

TABLE XVIII

REVERSED BENDING FATIGUE TEST RESULTS
2024 EXTRUSION PROCESSED AS NOTED
MAX STRESS ± 35,000 P.S.I. (R = -1)

SPEC. GROUP	PROCESSING PRIOR TO TESTING	TEST SECTION GRAIN DIRECTION	ROCKWELL "E"	MAX. SURFACE FINISH μ-IN		CYCLES TO FAILURE	REMARKS
15	NO STRETCH-SOL H.T. STRETCHED 6% IN W" COND.	TRANS	102.5	10	17	178,000	
"	" " " " " " " "	"	103.0	12	15	302,000	
"	" " " " " " " "	"	103.0	11	16	408,000	
"	NO STRETCH-SOL.H.T. STRETCHED 6% IN W" COND.	TRANS	102.0	11	18	142,000	GRIP FAILURE
	AVERAGE		102.6	11	16.5	257,250	
"	NO STRETCH-SOL.H.T. STRETCHED 6% IN W" COND.	LONG	104.1	15	26	99,000	
"	" " " " " " " "	"	102.6	15	25	149,000	
"	" " " " " " " "	"	103.7	20	27	187,000	
"	NO STRETCH-SOL.H.T. STRETCHED 6% IN W" COND.	LONG	103.0	12	27	218,000	
	AVERAGE		103.4	15.5	26	163,250	
16	NO STRETCH -SOL H.T. STRETCHED 10% IN W" COND.	TRANS.	105.0	12	17	236,000	
"	" " " " " " " "	"	105.0	12	16	232,000	
"	" " " " " " " "	"	105.0	11	16	116,000	
"	NO STRETCH-SOL H.T. STRETCHED 10% IN W" COND.	TRANS.	104.5	11	16	57,000	
	AVERAGE		104.9	11.5	16.25	160,250	
"	NO STRETCH -SOL.H.T. STRETCHED 10% IN W" COND.	LONG.	103.5	13	23	74,000	
"	" " " " " " " "	"	103.8	14	27	54,000	
"	" " " " " " " "	"	105.0	17	27	62,000	
"	NO STRETCH-SOL.H.T. STRETCHED 10% IN W" COND.	LONG.	103.5	21	29	47,000	GRIP FAILURE
	AVERAGE		104.0	16.25	26.5	53,250	

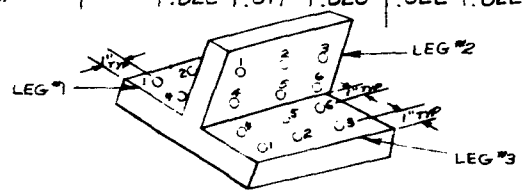
LONG. = LONGITUDINAL
TRANS. = TRANSVERSE
ALL FAILURES OCCURRED IN TEST SECTION EXCEPT AS NOTED.

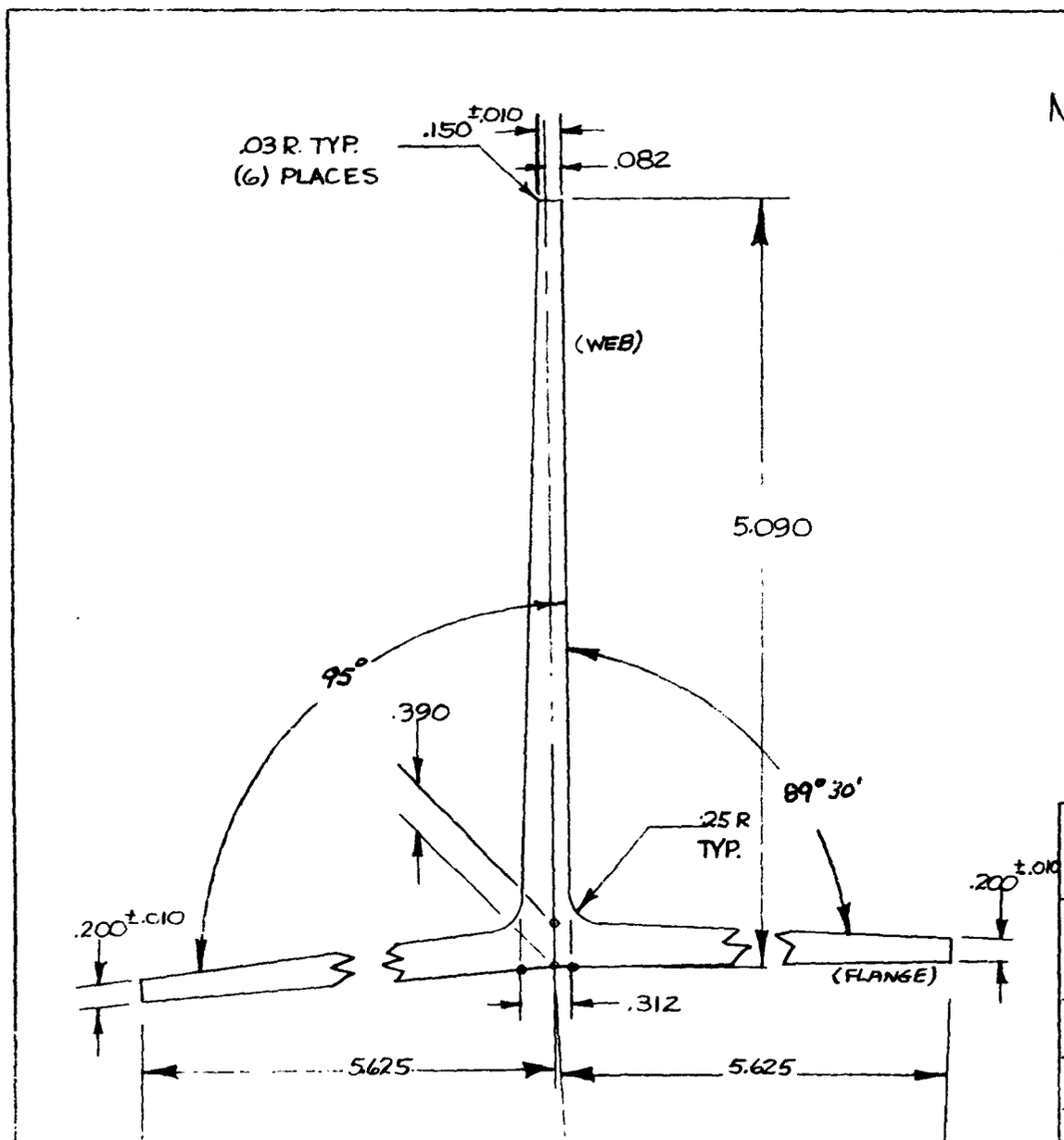
Prepared By [illegible]

TABLE XIX

REDUCTION IN THICKNESS DUE TO STRETCHING - 2024 EXTRU #E 801903

ITEM #	EXTRUSION PROCESSING / FIRST STRETCH OPERATION	STRETCH %	LEG #1 EDGE #1	LEG #1 EDGE #2	LEG #1 EDGE #3	LEG #1 #4	LEG #1 #5	LEG #1 #6	LEG #2 UPRIGHT EDGE #1	LEG #2 UPRIGHT EDGE #2	LEG #2 UPRIGHT EDGE #3	LEG #2 UPRIGHT #4	LEG #2 UPRIGHT #5	LEG #2 UPRIGHT #6	LEG #3 EDGE #1	LEG #3 EDGE #2	LEG #3 EDGE #3	LEG #3 #4	LEG #3 #5	LEG #3 #6
1	SOL. H.T. AFTER STRETCH	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	" " "	3.2	.010	.008	.008	.020	.020	018	.005	.009	.008	.005	.009	.009	.007	.006	.006	.012	.011	010
3	" " "	6.3	.011	.011	.009	.026	.026	.028	.014	.014	.015	.012	.013	.015	.012	.012	013	.021	.018	.019
4	" " "	9.5	.013	.013	.012	.019	.019	.020	.015	.018	.020	.017	.018	.018	.011	[illegible]	.012	.025	.028	.027
5	" " "	7.64	.014	.009	.009	.019	.018	.023	.016	.016	.016	.015	.012	.014	.010	.010	.010	.016	.016	.017
6	" " "	5.69	.004	004	.004	.009	011	.010	.011	.012	.013	012	.015	.015	.007	.008	.008	.007	.008	.010
7	" " "	5.97	.009	.006	.005	.016	.014	.012	.016	015	.013	.017	015	.012	.005	.004	.004	.009	.008	.007
8	" " "	5.83	.004	006	.003	.007	.010	.010	.010	.012	.011	.009	.011	.008	.003	.004	.005	.009	.010	.010
9	" " "	6.53	.004	005	.004	.008	.011	.012	.011	.010	.011	.009	.008	.008	.005	.004	005	.009	.009	.010
10	" " "	6.99	.004	.005	.005	.007	.008	.009	.009	.010	.010	.006	.007	.009	.006	.009	.005	.007	.009	.009
13	" " "	6.39	.003	.004	.003	.010	.010	.005	.005	.013	.010	.010	.009	.009	.003	.004	.005	.008	.009	.008
14	" " "	5.83	.006	.003	.006	.012	.010	.007	.012	.011	010	.017	.011	.012	007	.007	.006	.011	.011	.009
	SECOND STRETCH																			
5	STRETCHED IN "W" COND.	2.21	.008	.006	.006	.002	.005	.003	.002	.003	.002	.001	.007	.002	003	.005	.002	.001	.002	.002
6	" " "	3.15	.004	.006	.006	.006	.005	.010	.008	.006	.006	.009	.005	.006	.000	.001	.003	.007	008	.007
7	" "	4.72	.007	006	.006	.010	.014	.013	.006	.007	.008	.007	.008	.008	.005	.005	.005	.009	009	.011
9	" " "	6.00	.003	003	.003	.007	.007	007	007	.007	.009	.008	.008	008	.004	.004	.003	008	.006	.008
13	" " "	6.93	.010	.007	.008	013	.013	.015	.009	.007	.009	007	.006	.009	.012	.011	.013	.015	.015	.015
14	" " "	10.25	.014	.014	.014	.010	012	.014	.012	.010	.015	.008	.011	.011	.005	.004	.008	.020	.019	.023
8	STRETCHED AFTER AGE	4.02	001	.001	000	.017	.016	.012	.007	006	.008	.006	004	.006	.014	.013	.012	.010	.010	.008
10	" " " "	6.4	.008	.004	.002	.020	.013	.017	.013	.013	.010	.010	.011	.012	.014	.008	.013	.013	.011	.011
	1ST & 2ND STRETCH																			
5	" " "		.022	.015	.015	.021	.023	.026	018	.019	.018	.016	.019	.016	.013	.015	.012	.017	.018	.019
6	" " "		.008	.010	.010	.015	.016	.020	.019	.018	.019	.021	.020	.021	.007	.009	.011	.014	.016	.017
7	" " "		016	.012	.011	.026	.028	.025	.024	.025	.021	.024	.026	.020	.010	.009	.009	.018	.017	.018
9	" " "		.007	.008	.007	.015	.018	.019	.018	.017	.020	.017	.016	.016	.009	.008	.008	.017	.015	.018
13	" " "		.013	.011	.011	.023	.023	.020	.018	.020	.019	.017	.015	.018	.015	.015	.018	.023	.024	.023
14	" " "		.020	.017	.020	.022	.022	.021	.024	.021	.025	.025	.022	.023	.012	.011	.014	.031	.030	.032





NOTES:

(1) TOLERANCES PER QQ-A-245 (EXCLUDING TABLE 24) UNLESS NOTED.
(2) DIE NO. 24324, VENDOR-HARVEY
(3) AREA 4.40
(4) DIMENSIONS SHOWN ARE THE DIMENSIONS PRIOR TO STRETCHING.

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Model 22
Date 25 June '58

STRUCTURAL TEST
CONVAIR - SAN DIEGO
A DIVISION OF GENERAL DYNAMICS

TITLE
TEE-EQUAL LEGS & UNEQUAL ANGLES

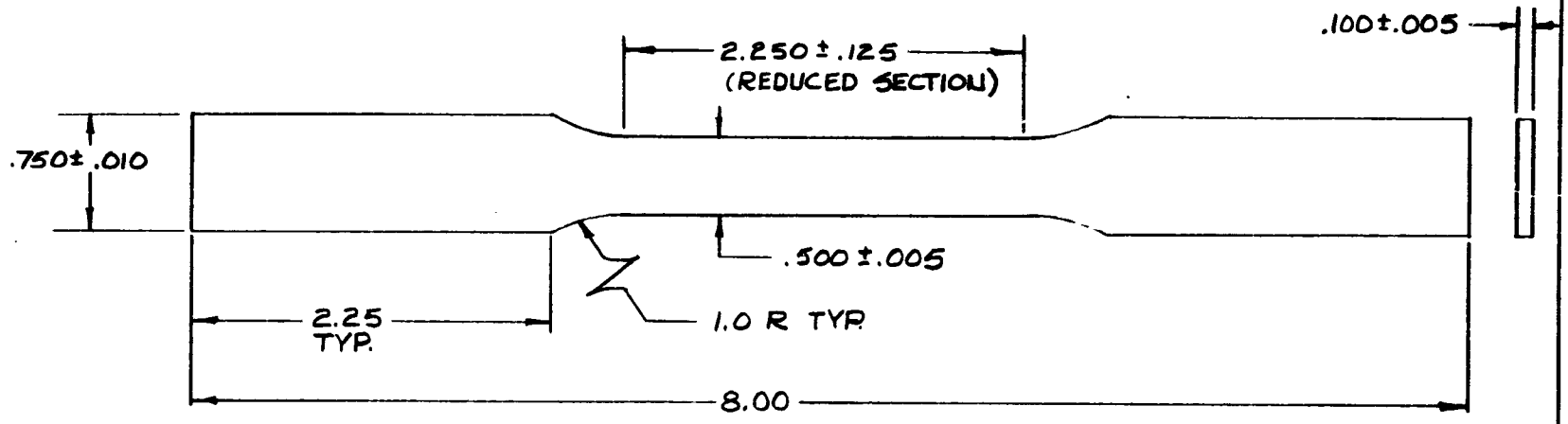
MODEL	SCALE	DATE	DRAWN BY
			R. Hann

S.O.	DRAWING NUMBER
W.O.	E 801903

6-899

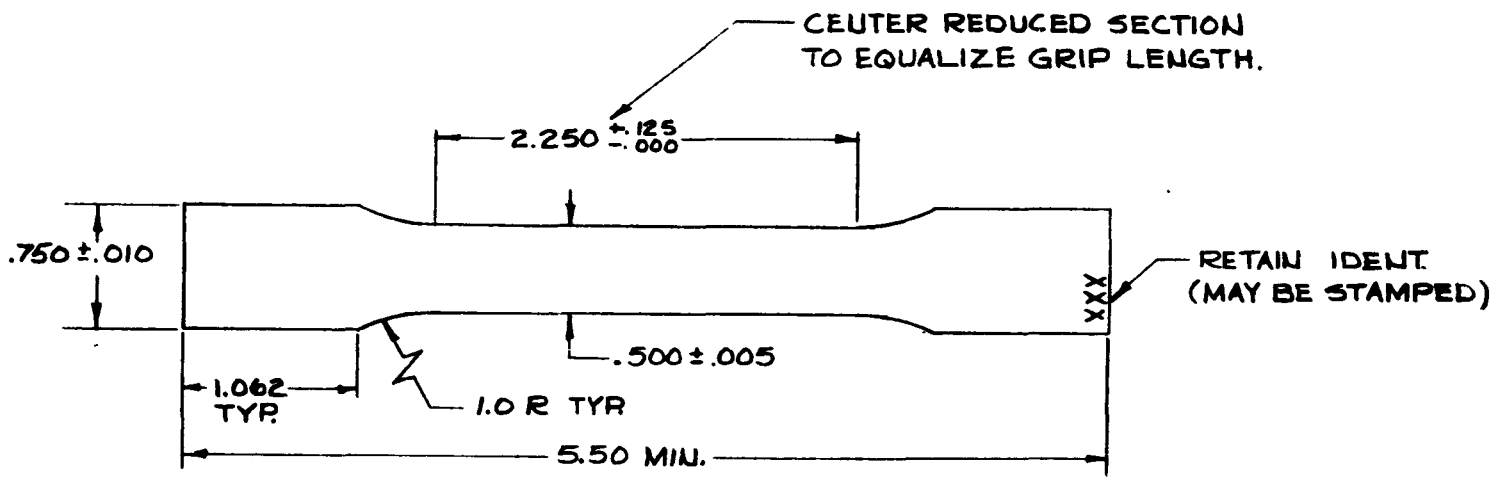
CONVAIR SD - 3213

FIGURE 1



STRUCTURAL TEST CONVAIR - SAN DIEGO A DIVISION OF GENERAL DYNAMICS			
TITLE STANDARD TENSILE LONGITUDINAL			
MODEL	SCALE FULL	DATE 4-10-58	DRAWN BY BRIGHT
S.O.	DRAWING NUMBER		
W.O.			

FIGURE 2



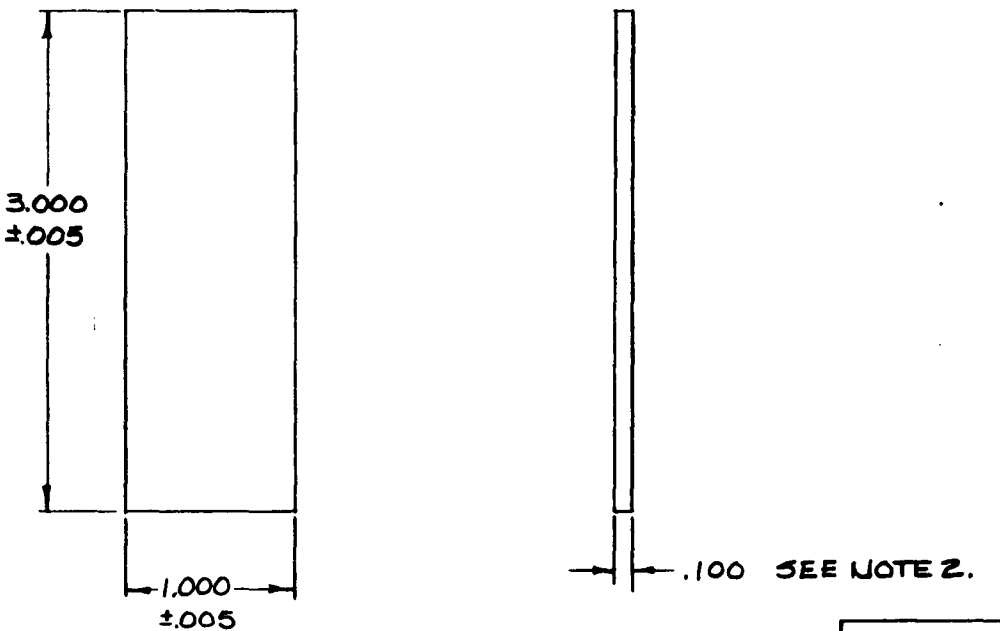
STRUCTURAL TEST
CONVAIR - SAN DIEGO
A DIVISION OF GENERAL DYNAMICS

TITLE
SUB-SIZE TENSILE
LONG TRANSVERSE

MODEL	SCALE	DATE	DRAWN BY
	FULL	4-10-58	BRIGHT

S.O.	DRAWING NUMBER
W.O.	

FIGURE 3

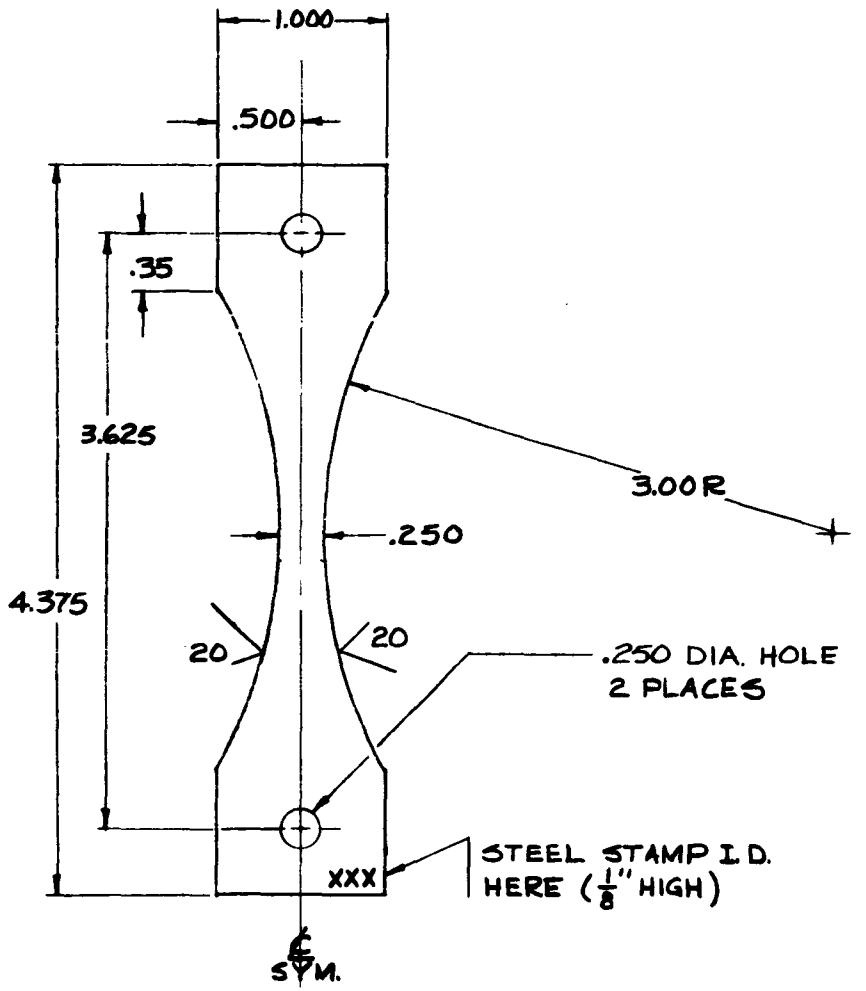


NOTES:

1. RETAIN RED INK IDENTIFICATION. DO NOT STEEL STAMP
2. MAX. TAPER .002 – .005 END TO END.
3. ENDS MUST BE FLAT AND PARALLEL. PERMISSIBLE ANGULAR DEVIATION 0°15'

STRUCTURAL TEST CONVAIR - SAN DIEGO A DIVISION OF GENERAL DYNAMICS			
TITLE COMPRESSION SPECIMEN LONGIT. & LONG TRANSVERSE			
MODEL	SCALE FULL	DATE 4-10-58	DRAWN BY BRIGHT
S.O.	DRAWING NUMBER		
W.O.			

FIGURE 4



NOTES:

1. THERE ARE TO BE NO NICK, SCRATCHES OR UNDERCUTS IN TEST SECTION
2. $K_t = 1.025$
3. TOLERANCES:
   .XX ±.030
   .XXX ±.010

STRUCTURAL TEST CONVAIR - SAN DIEGO A DIVISION OF GENERAL DYNAMICS			
TITLE: AXIAL FATIGUE SPECIMEN UNNOTCHED			
MODEL: 22	SCALE: FULL	DATE: 4-1-58	DRAWN BY: BRIGHT
S.O.: 4330	DRAWING NUMBER: 57-997-1		
W.O.: 30573			

FIGURE 5

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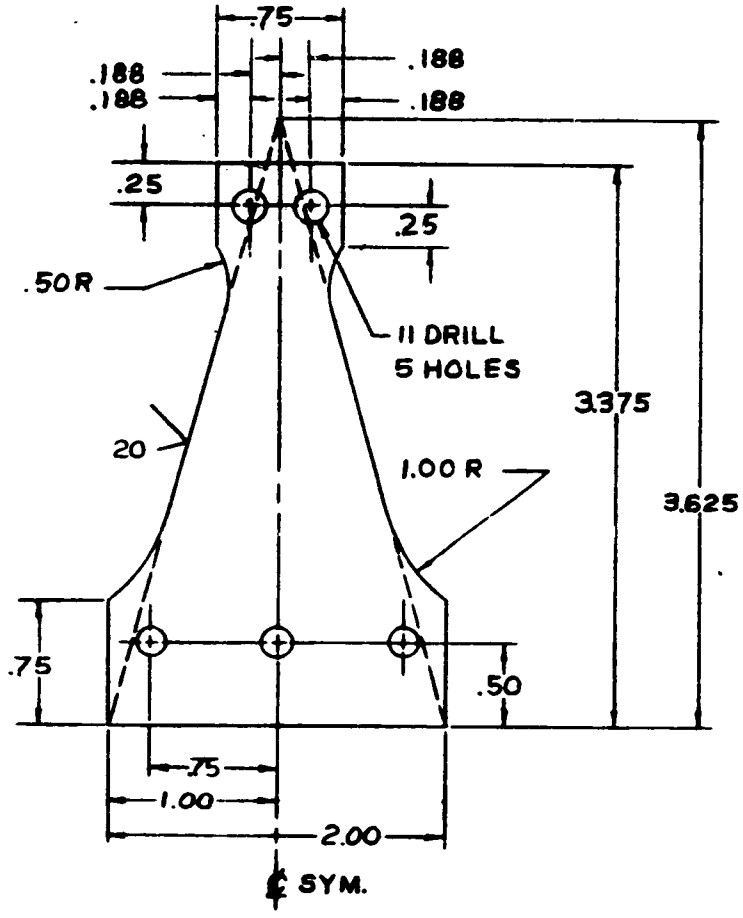
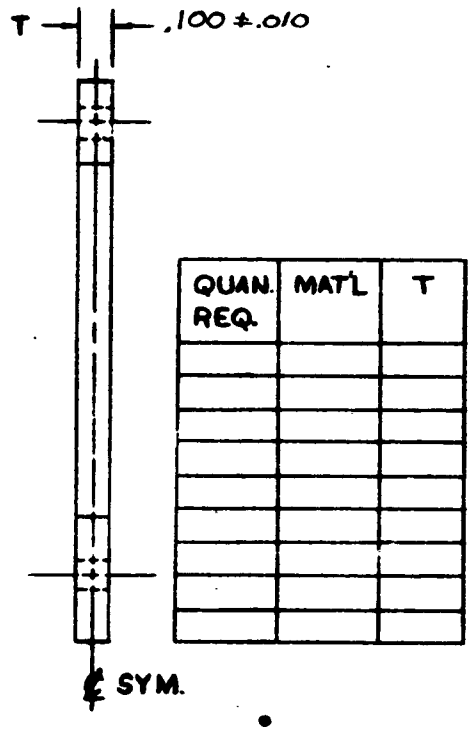
6-899

CONVAIR SD - 3213





NOTES:

1. THERE ARE TO BE NO NICKS, SCRATCHES, OR UNDERCUTS IN TEST SECTION.
2. DO NOT GRIND

STRUCTURAL TEST
CONVAIR - SAN DIEGO
A DIVISION OF GENERAL DYNAMICS

TITLE

STANDARD FATIGUE SPECIMEN
UNNOTCHED-SHEET BENDING

MODEL	SCALE	DATE	DRAWN BY
R&D	FULL	1-16-57	BRIGHT

S.O.

W.O.

DRAWING NUMBER

10030

6-099

CONVAIR SD - 3213

FIGURE 8

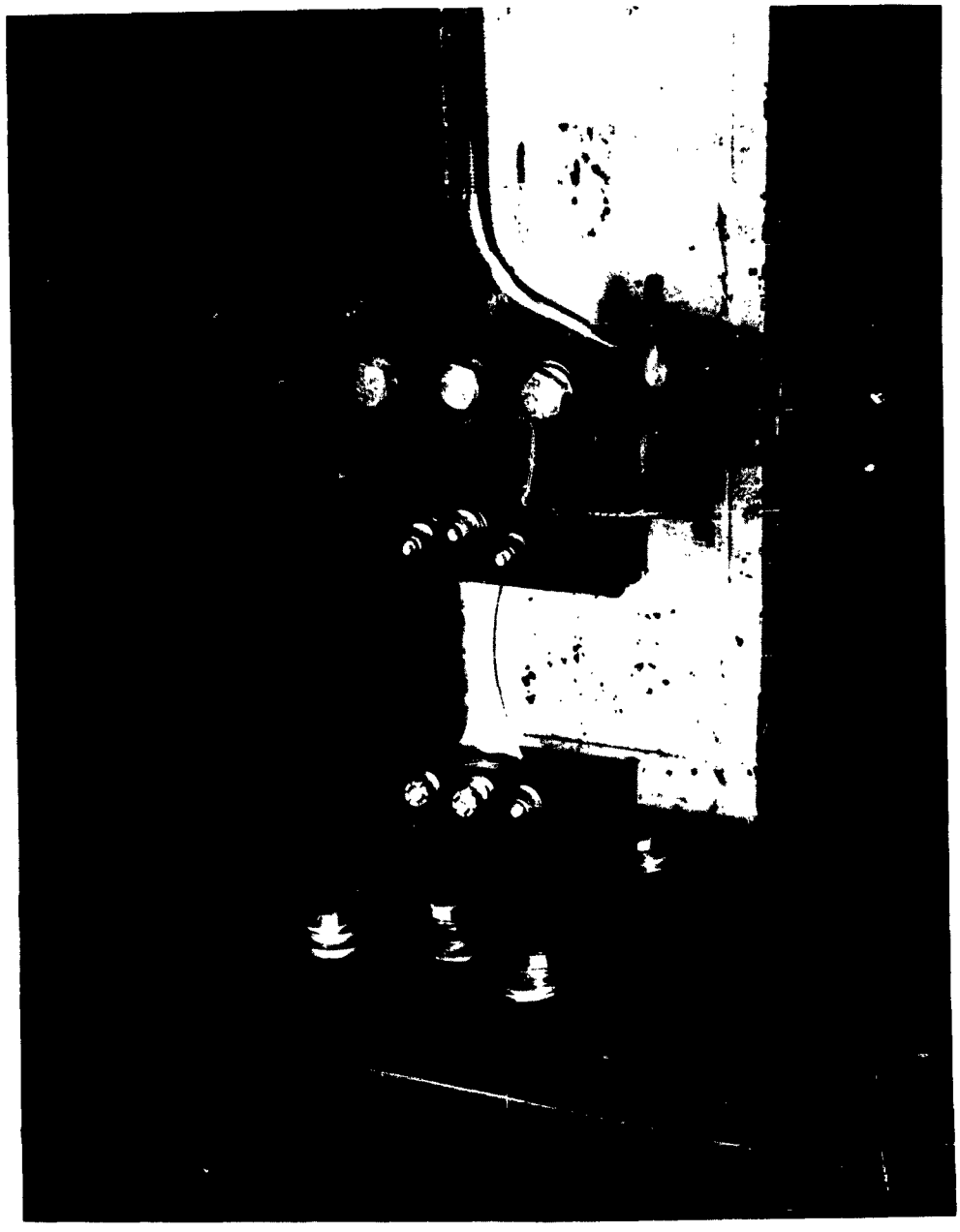


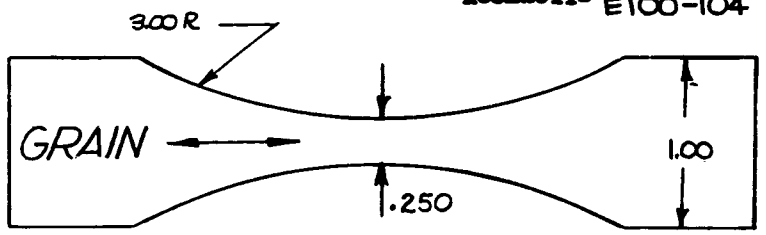
Figure 7 AXIAL FATIGUE TEST SET-UP

Figure 8 BENDING FATIGUE TEST SET - UP

Prepared By: R. J. Haney
G. Lindeman

CONVAIR
A Division of General Dynamics Corporation
Division

MATERIAL: 2024 -VARIOUS % STRETCH & H.T. SEQUENCE
Mfr HARVEY Ht. No. REF TABLES Form: EXTRUSION
F_{tu} DIE #24324 F_{ty} = I & II %El. = —
SPECIMEN (Sketch and Dimensions) Surf. Fin.-20μ-IN. OR BETTER
Rockwell- E100-104



TEST SECTION CORRESPONDS TO A.I.A. AXIAL TENSION SPEC. #17
TEST CONDITIONS: Machine SF-10
R = +.05 Mean Stress =
Other
Speed 1800 C.P.M. Temp APPROX 70°F
Date: Kt (Net Section) = 1.025

MAXIMUM STRESS (PSI x 10^3)

60
50
40
30

UPPER LIMIT OF DATA
LOWER LIMIT OF DATA

CYCLES

10^3 10^4 10^5 10^6 10^7 10^8

FIGURE 9

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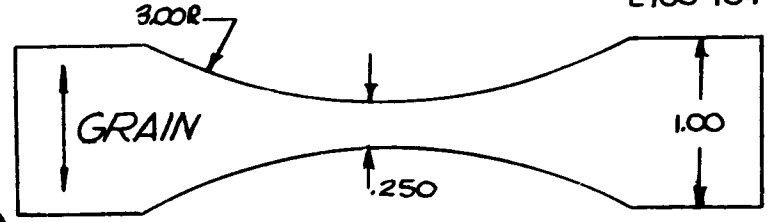
Report No. 57-007
Model 22
Date 25 June 1956

Prepared By. R. J. Honey
A. Lindenau

C O N V A I R
A Division of General Dynamics Corporation
Division

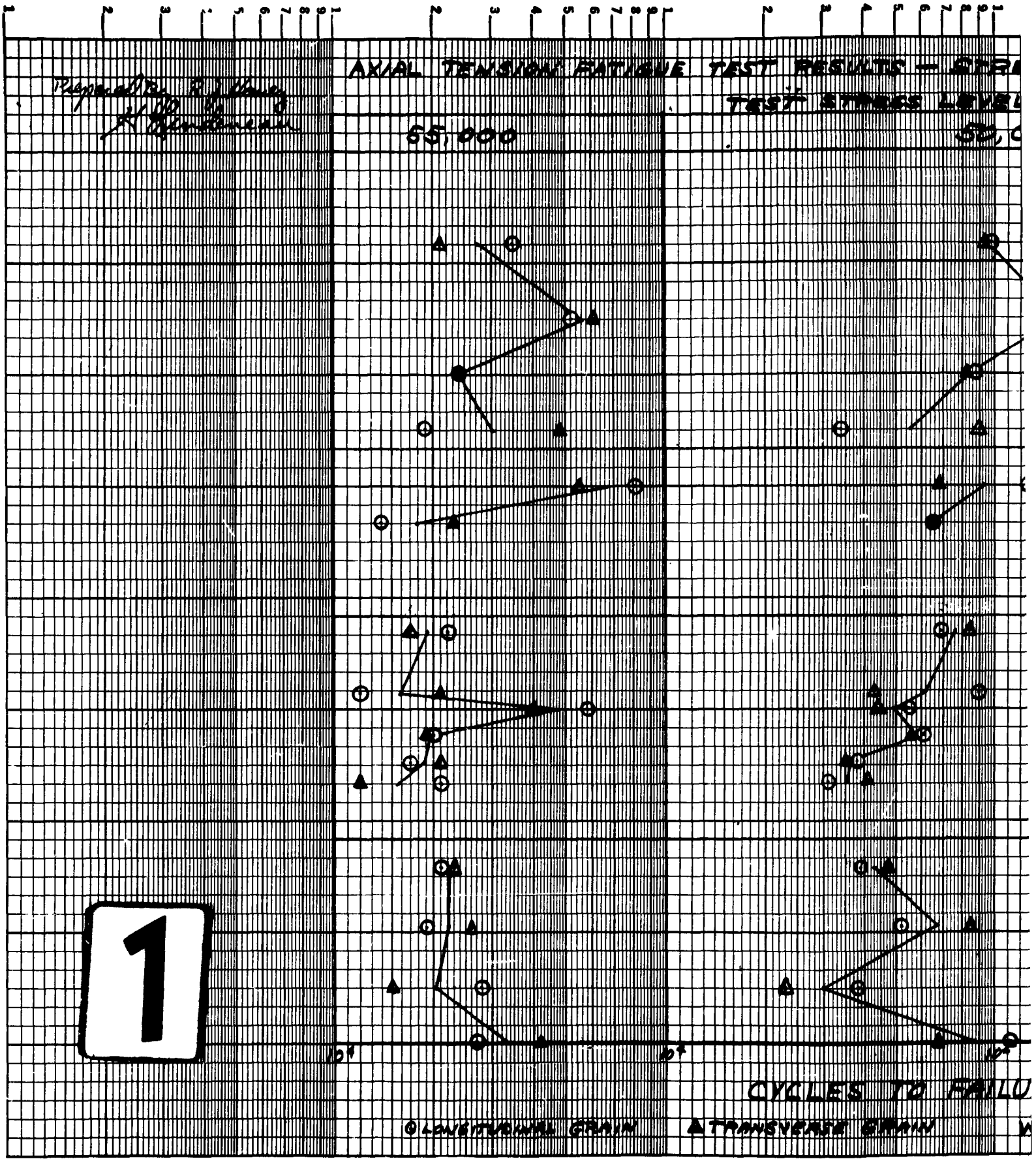
MATERIAL: 2024-VARIOUS % STRETCH & H.T. SEQUENCE
Mfr HARVEY Ht. No. REF TABLES Form: EXTRUSION
Ftu DIE = 24324 Fty = I & II %El. = —
SPECIMEN (Sketch and Dimensions) Surf. Fin.- 20 μ-IN. OR BETTER
Material- E100-104



TEST SECTION CORRESPONDS TO AIA AXIAL TENSION SPEC #7

TEST CONDITIONS: Machine SF-1U
R = +.05 Mean Stress =
Other
Speed 1800 CPM Temp APPROX 70°F
Date: Kt (Net Section) = 1.025

FIGURE 10


AXIAL TENSION FATIGUE TEST RESULTS — SPEA
TEST STRESS LEVEL
65,000
52,0
1
CYCLES TO FAILU
LONGITUDINAL GRAIN
TRANSVERSE GRAIN

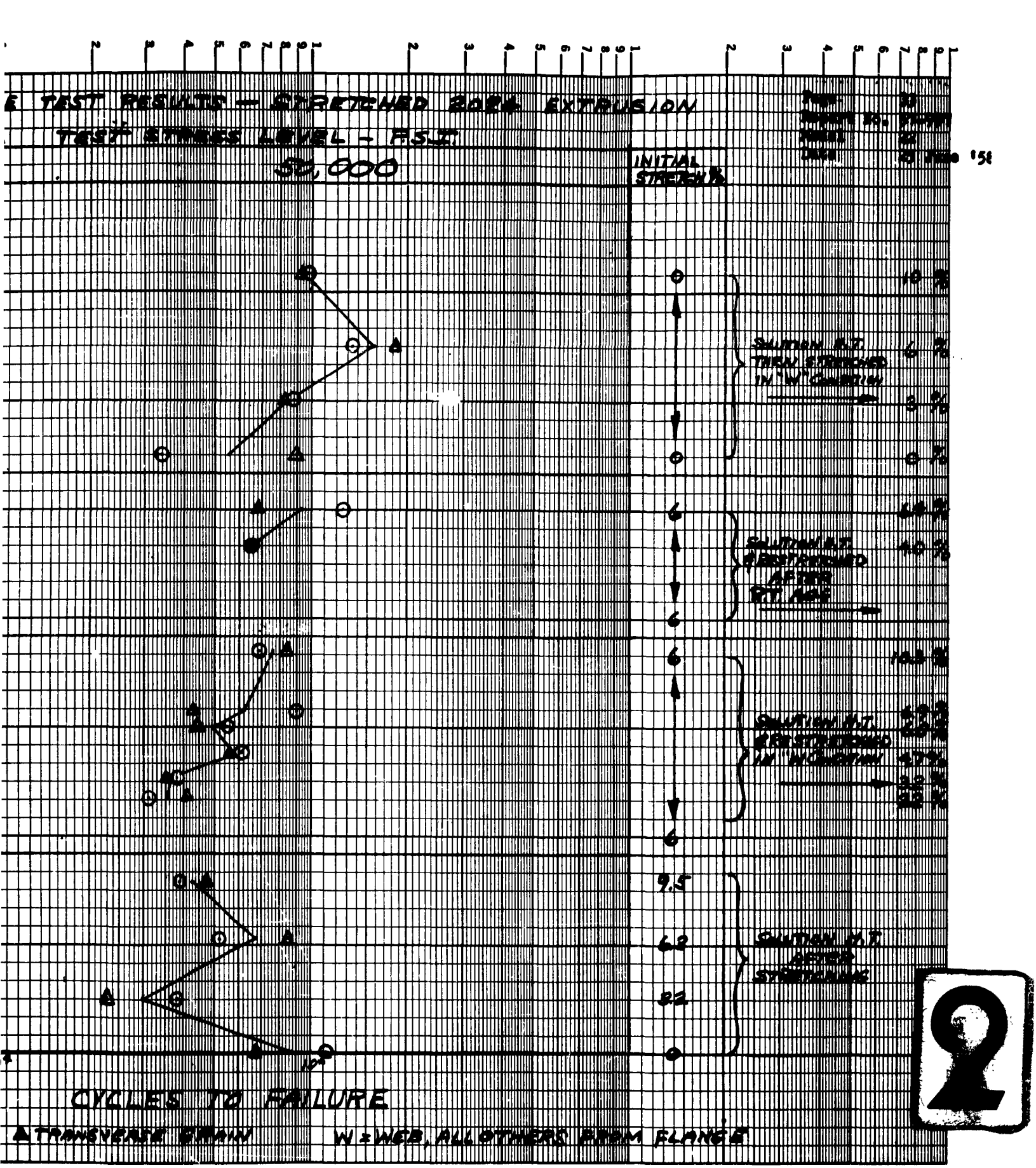
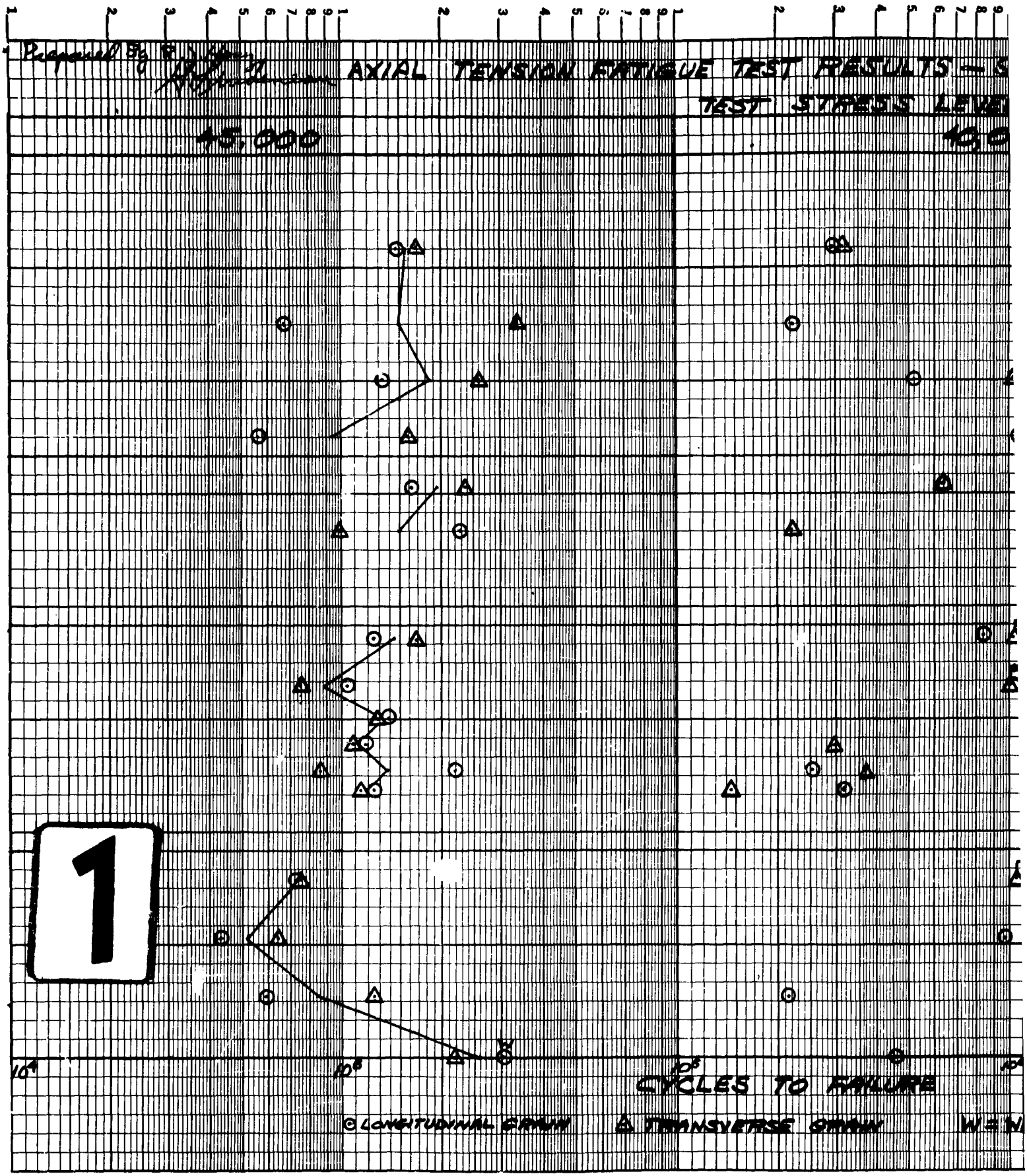

TEST RESULTS — STRETCHED 2024 EXTRUSION
TEST STRESS LEVEL - PSI
32,000
INITIAL STRETCH %
SOLUTION A.T. THEN STRETCHED IN "W" DIRECTION
SOLUTION A.T. STRETCHED AFTER AGE
SOLUTION A.T. STRETCHED IN "W" DIRECTION
SOLUTION A.T. AFTER STRETCHING
6
9.5
6.2
8.2
CYCLES TO FAILURE
▲ TRANSVERSE STRAIN
W = WEB, ALL OTHERS FROM FLANGE

FIGURE 11


Prepared by
AXIAL TENSION FATIGUE TEST RESULTS — S
TEST STRESS LEVE
45,000
40
1
10^4
10^5
10^6
CYCLES TO FAILURE
LONGITUDINAL GRAIN
TRANSVERSE GRAIN
W = M

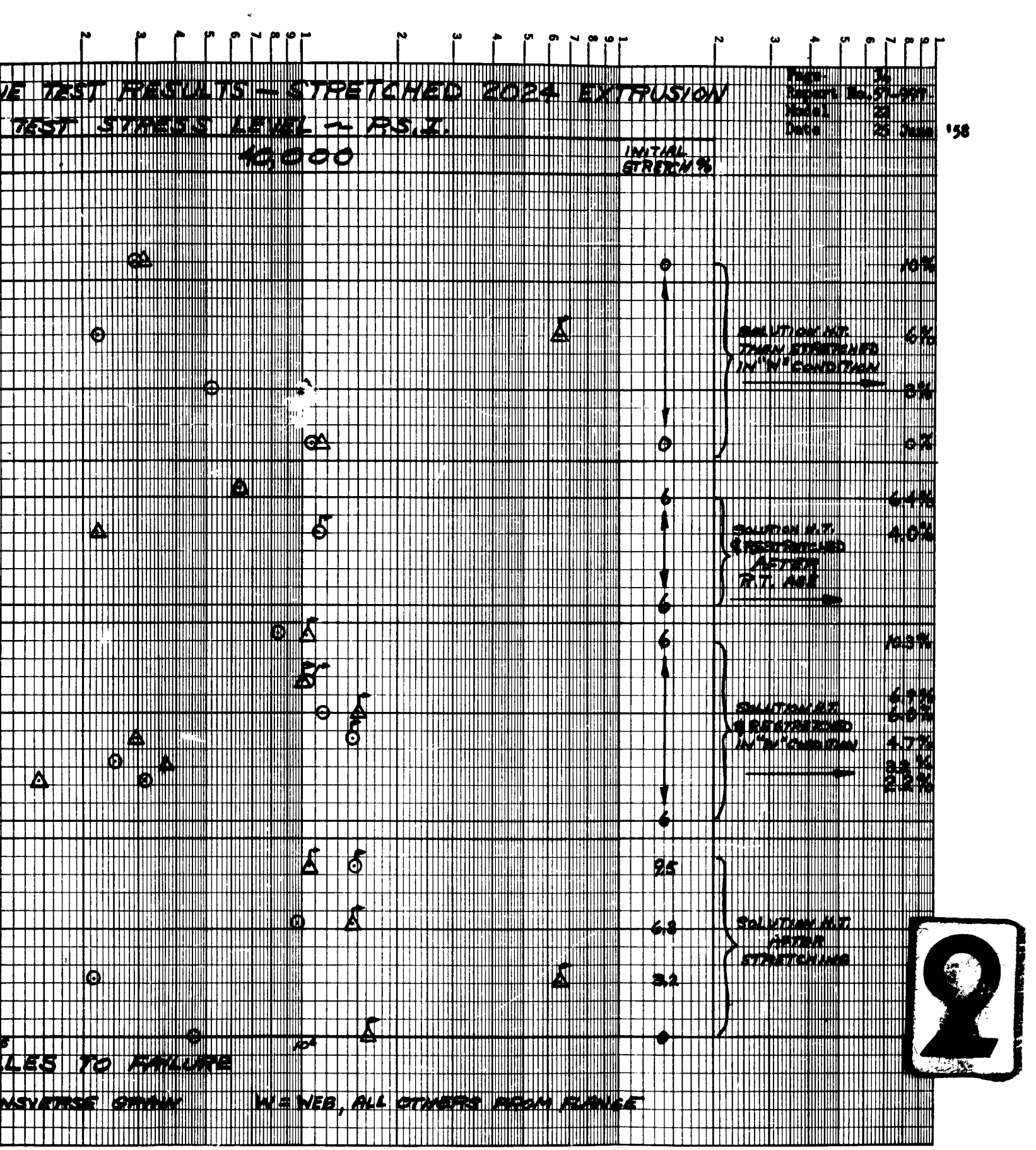
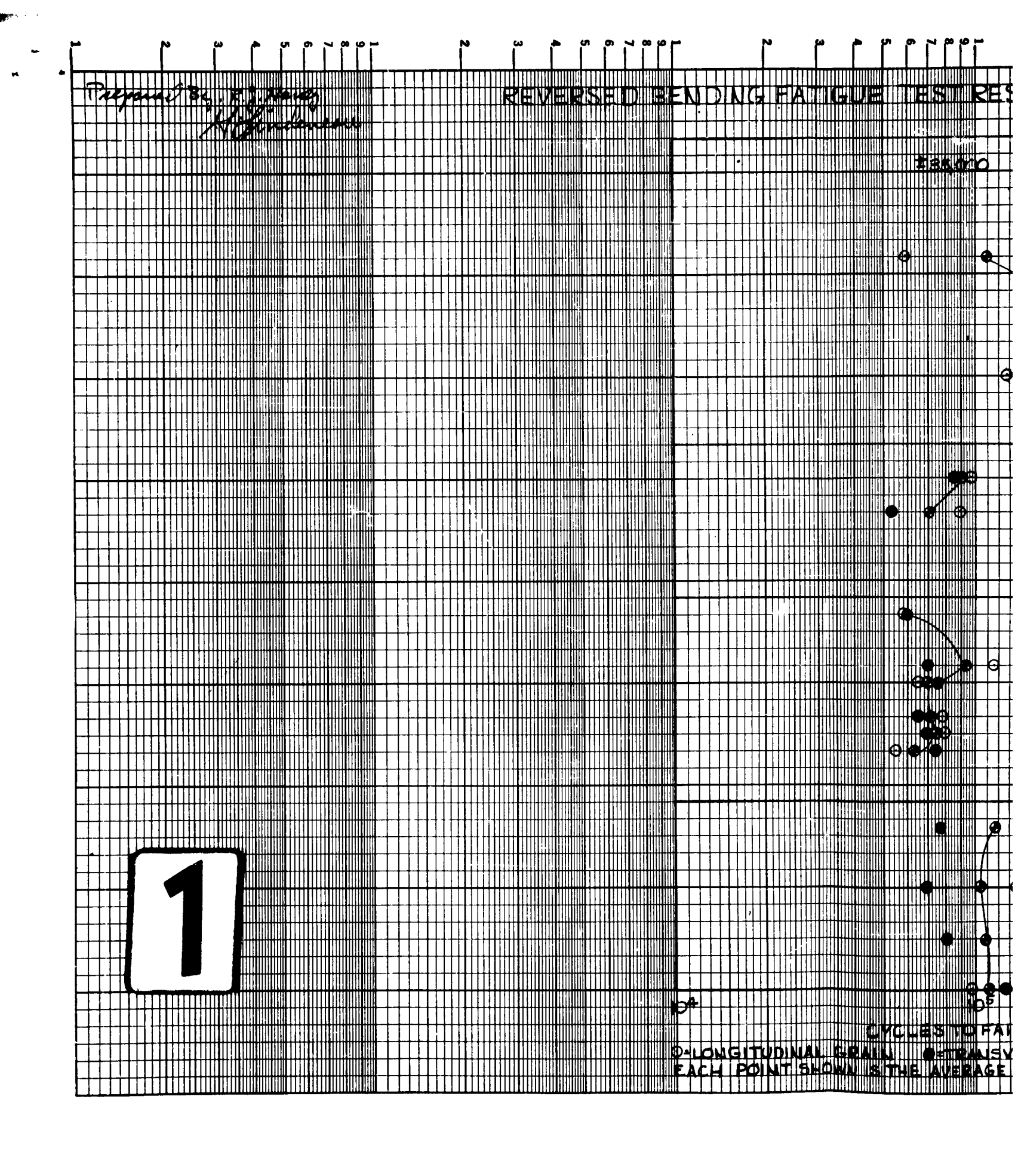

E TEST RESULTS — STRETCHED 2024 EXTRUSION
TEST STRESS LEVEL — R.S.I.
40,000
INITIAL STRETCH %
SOLUTION HEAT TREAT, STRETCHED IN "W" CONDITION
SOLUTION H.T. & REFRIGERATED AFTER R.T. AGE
SOLUTION H.T. & RE-STRETCHED IN "W" CONDITION
SOLUTION H.T. AFTER STRETCHING
10%
6%
0%
0%
6.4%
4.0%
6
6
6
10.3%
4.0%
4.0%
4.7%
3.2%
2.2%
6
2.5
6.8
3.2
LES TO FAILURE
W = WEB, ALL OTHERS FROM FLANGE

FIGURE 12


REVERSED BENDING FATIGUE TESTRES
±35,000
CYCLES TO FAI
○-LONGITUDINAL GRAIN
EACH POINT SHOWN IS THE AVERAGE

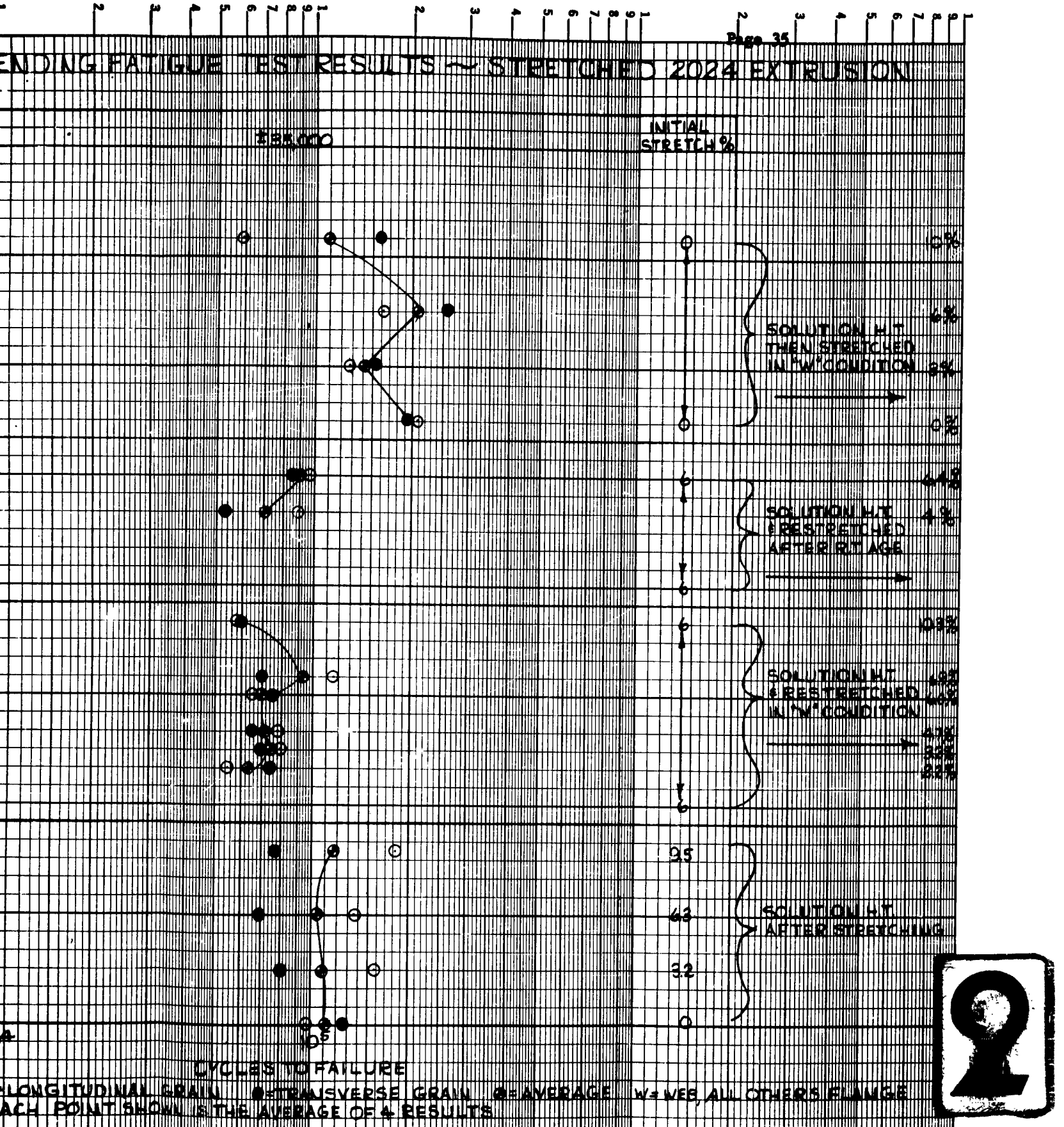

ENDING FATIGUE TEST RESULTS ~ STRETCHED 2024 EXTRUSION
INITIAL STRETCH %
SOLUTION H.T. THEN STRETCHED IN "W" CONDITION
SOLUTION H.T. & RESTRETCHED AFTER RT AGE
SOLUTION H.T. & RESTRETCHED IN "W" CONDITION
SOLUTION H.T. AFTER STRETCHING
10%
6%
2%
0%
4%
10%
6%
4%
2%
0%
CYCLES TO FAILURE
LONGITUDINAL GRAIN ⊗=TRANSVERSE GRAIN ⊙=AVERAGE W=WEB, ALL OTHERS FLANGE
EACH POINT SHOWN IS THE AVERAGE OF 4 RESULTS

FIGURE 13

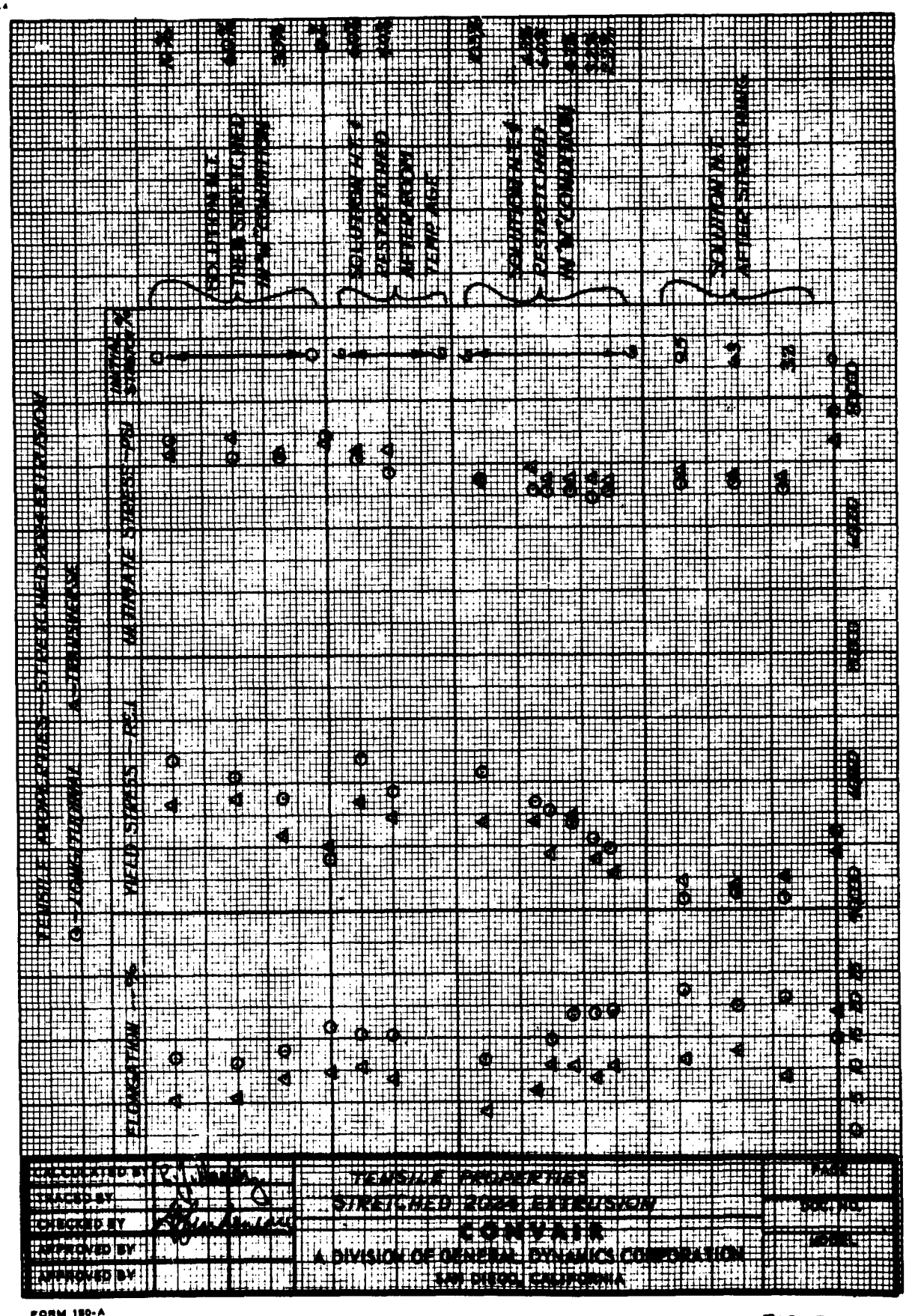

TENSILE PROPERTIES—STRETCHED 2022 EXTRUSION
ULTIMATE STRESS—KSI
YIELD STRESS—KSI
ELONGATION—%
SOLUTION TREATED
STRETCHED 1%
ROOM TEMP AGE
STRETCHED 2%
ROOM TEMP AGE
STRETCHED 3%
ROOM TEMP AGE
SOLUTION TREATED
ROOM TEMP AGE
TENSILE PROPERTIES
STRETCHED 2022 EXTRUSION
CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO, CALIFORNIA
FORM 150-A

FIGURE 14